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Characterization of Sulfates, Odor, Smoke, POM and Particulates from Light and Heavy Duty Engines - Part IX

Southwest Research Inst, San Antonio, TX

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This report expands EPA's data base on regulated and unregulated emissions from Diesel powered cars and trucks. To the extent possible, comparisons were made to similar vehicles powered by gasoline fueled engines. Emissions, fuel economy and general performance of a pair of gasoline-and Diesel-powered Volkswagen Rabbit and Oldsmobile Cutlass cars are discussed. Characterization of heavy-duty engines included a Mack ETAY(B)673A and a Caterpillar 3208, both Diesels, and a Chevrolet 366 gasoline fueled engine. A pair of Daimler-Benz Diesels, one turbocharged and the other not, were used to evaluate the effect of turbocharging. A high pressure injection system was tried with the Mack engine and compared to the standard system. A Caterpillar 3406 Diesel was used to investigate the effect of injection timing, combustion system and exhaust gas recirculation on exhaust particulate and other emissions.

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CHARACTERIZATION OF SULFATES, ODOR, SMOKE, POM AND PARTICULATES FROM LIGHT AND HEAVY DUTY ENGINES - PART IX

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FOREWORD

This project was conducted for the U.S. Environmental Protection Agency by the Department of Emissions Research, Automotive Research Division of Southwest Research Institute. The EPA Project Officer was Mr. Thomas M. Baines.

This project was under the overall direction of Mr. Karl J. Springer, Director of the Department of Emissions Research, who served as Project Manager. Mr. Terry L. Ullman was responsible for the experimental laboratory evaluations of part Ib dealing with particulate-engine effects. The project began July 7, 1976 and was authorized by Contract No. 68-03-2417. It was known within Southwest Research Institute as Project No. 11-4623 and constituted Part IX of a long-range investigation of Diesel emissions begun in 1966.

ABSTRACT

This report expands EPA's data base on regulated and unregulated emissions from Diesel-powered cars and trucks. To the extent possible, comparisons were made to similar vehicles powered by engines that use gasoline as a fuel. For example, one part of the report is a comparison of the emissions, fuel economy, noise and acceleration characteristics of a pair of Volkswagen Rabbit and a pair of Oldsmobile Cutlass passenger cars. Each pair included a vehicle powered by a Diesel engine and a vehicle powered by a gasoline engine. Emissions characterization of heavy-duty engines included a Caterpillar 3208 with exhaust gas recirculation (EGR), and a Mack ETAY(B)673A (both Diesels) and a Chevrolet 366 Heavy-Duty Gasoline (HDG) engine. The effect of several engine parameters on particulate and sulfate emissions is also discussed. A Caterpillar 3406 Heavy-Duty Diesel (HDD) engine was operated at several timings, with EGR, and in an open chamber (direct injected) as well as prechamber configuration. A pair of Daimler-Benz OM-352 HDD engines, one turbocharged and one not, were used to evaluate the effect of turbocharging. An American Bosch APS high pressure fuel injection system was compared to the standard system using the Mack ETAY(B)673A HDD engine. The passenger car studies were based on recognized transient chassis dynamometer driving cycles for city, congested freeway, and highway type operation. The HDD engines were operated by mainly the 13-mode Federal cycle, or short versions thereof, on a stationary dynamometer. Emissions of major interest were unburned hydrocarbons, carbon monoxide, carbon dioxide, oxides of nitrogen, sulfate, particulate, smoke, odor, various aldehydes and specific hydrocarbons, benzo(a)pyrene, and particle size distribution. In all cases, vehicle fuel economy or engine fuel efficiency was obtained and reported.

TABLE OF CONTENTS

Page

FOREWORD iii

ABSTRACT iv

LIST OF FIGURES vii

LIST OF TABLES x

I. SUMMARY 1

- A. Heavy-Duty Engine Characterization 1
- B. Engine Effects on Particulate/Sulfate 2
- C. Evaluation of Passenger Cars Equipped with Diesel and Gasoline Engines 4

II. INTRODUCTION 6

- A. Background 6
- B. Objective 6
- C. Publication/Presentation 7
- D. Acknowledgement 7

III. DESCRIPTION OF ENGINES, VEHICLES, FUELS, AND PROCEDURES 8

- A. Heavy-Duty Engines 8
- B. Light-Duty Vehicles 10
- C. Test Fuels and Lubricants 12
- D. Test Plans 15
- E. Procedures and Analysis 17
- F. Weighting Factors - HD Engines 42

IV. RESULTS OF HEAVY-DUTY ENGINE CHARACTERIZATION 46

- A. Gaseous Emissions 46
- B Smoke Results 53
- C. Particulate and Sulfate Results 56
- D. Elemental and Metal Analyses 76
- E. Benzo(α)pyrene Analyses 79
- F. Odor and Related Instrumental Analyses 84
- G. Aldehydes 94
- H. Specific Hydrocarbons 97

V. SULFATE AND PARTICULATE CHARACTERIZATIONS 101

- A. Effect of Timing, EGR and Combustion System 102
- B. Effect of Turbocharging 136
- C. Effect of Injection System 148
- D. Effect of Fuel Residue 165

TABLE OF CONTENTS (Cont'd.)

Page

VI. RESULTS OF LIGHT-DUTY VEHICLE EVALUATION 169

- A. Regulated Emissions and Fuel Economy 169
- B. Smoke Results 173
- C. Particulate 178
- D. Sulfate 181
- E. Carbon-Hydrogen-Nitrogen 185
- F. Metals 186
- G. Odor Ratings and Related Analysis 186
- H. Aldehydes 191
- I. Specific Hydrocarbons 198
- J. Polynuclear Aromatics 198
- K. Noise 202
- L. Performance 202

LIST OF REFERENCES 205

APPENDICIES

- A. Experimental 23-Mode Test Procedure for Engines in Heavy-Duty Motor Vehicles
- B. Chemical-Analytical Procedures
- C. Emissions Characterization Data for Mack ETAY(B)673B Caterpillar 3208 w/EGR and Chevrolet 366 Heavy-Duty Engines
- D. Sulfate and Particulate Characterization
- E. Computer Reduced 1975 FTP, SET and FET Gaseous and Fuel Economy Data for Four LD Vehicles
- F. Unregulated Emissions for Four LD Vehicles

LIST OF FIGURES

Figure | | Page

1 Stationary Test of Heavy-Duty Diesel and Gasoline Engines 19

2 Speed Versus Time Traces of FTP, HFET, and SET-7 Driving Cycles 21

3 Oldsmobile and Volkswagen Diesel- and Gasoline-Powered Passenger Cars Under Test 22

4 Schematic of One Cycle of Federal Smoke Compliance Test Engine Speed Versus Time 24

5 Smoke and Odor Measurement Equipment 25

6 Gaseous Emissions Measurement Instruments and Apparatus 32

7 Schematic Section of Dilution Tunnel for Diesel Particulate Sampling 34

8 Particulate Measuring Equipment (HD Engines) 36

9 LDV Particulate Sulfate and Noise Measurement Equipment 38

10 Caterpillar 3208 with Automatic EGR 50

11 Comparison of Gaseous Emissions and Specific Fuel Consumption of Caterpillar 3208 EGR and Chevrolet 366 Engines (23-Mode EPA Test) 54

12 Particulate Emission Rates from Mack ETAY(B)673A Truck Engine, Based on 47 mm Glass Filters 63

13 Sulfate $(SO_4^=)$ Emission Rates from Mack ETAY(B)673A Truck Engine, Based on 47 mm Fuloropore Filters 64

14 Power Output, Fuel and Air Rates from Mack ETAY(B)673A Truck Engine 65

15 Particulate Emission Rates from Caterpillar 3208 and Chevrolet 366 Truck Engines Based on 47 mm Glass Filters 68

16 Sulfate $(SO_4^=)$ Emission Rates from Caterpillar 3208 and Chevrolet 366 Truck Engines, Based on 47 mm Fluoropore Filters 69

LIST OF FIGURES (Cont'd.)

Figure		Page
17	Power Output, Fuel and Air Rates from Caterpillar 3208 EGR and Chevrolet 366 Truck Engines	72
18	Comparison of Cycle Weighted Particulate and Sulfate Emission Rates - Caterpillar 3208 EGR and Chevrolet 366	75
19	Cycle Composite BaP Comparison Caterpillar 3208 EGR and Chevrolet 366	83
20	Mack ETAY(B)673A Engine Diesel Odor Intensity by Trained Panel	88
21	Caterpillar 3208 EGR Engine Diesel Odor Intensity by Trained Panel	89
21a	"D" Odor Ratings Versus TIA Mack ETAY(B)673A and Caterpillar 3208 EGR	92
22	Comparison of TIA Values Based on 3-Run Average and 3-Run Composite Samples - Caterpillar 3208 EGR	95
23	Anderson Mark III In-Stack Sampler - Used for Diesel Particle Sizing	109
24	Anderson Impactor Stage Collection Foils and Back-up Filter	110
25	Effect of Basic Timing on Sulfate and Particulate Caterpillar 3406 DI	115
26	Particulate and Sulfate Modal Rates for Different Static Injection Timings, Caterpillar 3406 DI	117
27	Particle Size Distribution by "Means" for Caterpillar 3406 DI, via Impactor	119
28	Effect of Timing on TIA Caterpillar 3406 DI Version	121
29	Particulate and Sulfate Modal Rates for Caterpillar 3406 DI With and Without EGR	125
30	Modal Smoke and Particulate, Caterpillar 3406 DI With and Without EGR	126
31	Effect of EGR on TIA Caterpillar 3406 DI Version	129

LIST OF FIGURES (Cont'd.)

Figure		Page
32	Particulate and Sulfate Modal Rates for Caterpillar 3406 DI Open Chamber and IDI Prechamber	133
33	Particulate and Sulfate Modal Rates for Daimler-Benz OM-352 and OM-352A Diesel Engines	141
34	Particle Size Distribution by "Means" for Daimler-Benz OM-352, via Impactor	145
35	Effect of Turbocharging on TIA, Daimler-Benz OM-352A and OM-352 Engines	146
36	Simplified Schematic of APS Pump Setup	149
37	American Bosch APS Pump Installed on Mack ETAY(B)673A	150
38	Injection Pressure Photos for Mack ETAY(B)673A Diesel with A. Bosch APS High-Pressure Injection System	152
39	Particulate and Sulfate Modal Rates for Mack ETAY(B)673A with APS and Standard Pumps	158
39a	Particle Size Distribitions by "Means" for ETAY(B)673A, via Impactor	160
40	Typical Oldsmobile Cutlass Diesel "Cold Start" Smoke Trace	176
41	Typical Volkswagen Rabbit Diesel "Cold Start" Smoke Trace	177
42	Particulate Emission Rates for Diesel- and Gasoline-Powered Passenger Cars	180
43	Sulfate Emission Rates for Diesel- and Gasoline-Powered Passenger Cars	183
44	Average Odor Ratings for Cutlass Diesel Car	189
45	Average Odor Ratings for Rabbit Diesel Car	190
46	TIA by DOAS Versus "D" Odor Rating by Trained Panel for Two Diesel Cars at Two Dilution Levels	193
47	TIA of Various Driving Cycles for Diesel-Powered Passenger Cars	194
48	Aldehyde Emission Rates for Diesel- and Gasoline-Powered Passenger Cars	197

LIST OF TABLES

Table		Page
1	Description of Heavy-Duty Diesel Engines	9
2	Description of Light-Duty Test Vehicles	11
3	Description of Test Fuels	13
4	"National Average" Properties from Fuel Surveys	14
5	Odor Test Conditions - HD Engines	28
6	Odor Test Conditions	29
7	EPA 23-Mode Weighting Factors and Short Cycle Weighting Factors Derived Therefrom	43
8	13-Mode FTP Weighting Factors and Short Cycle Weighting Factors Derived Therefrom	44
9	EPA 23-Mode and 13-Mode FTP Gaseous Emissions Rates	47
10	Heavy-Duty Diesel and Gasoline Emission Limits	48
11	Federal Smoke Test Results for Mack ETAY(B)673A and Caterpillar 3208 EGR Diesel Engines	55
12	Smoke Measured During Modal Testing (Caterpillar 3208 with EGR)	57
13	Caterpillar 3208 EGR Left and Right Bank Smoke Levels	58
14	Summary of Particulate and Sulfate Emission Rates (Based on 47 mm Fiberglass and Fluoropore Samples)	59
15	Summary of Engine Operating Conditions 47 mm Glass and Fluoropore Filter Tests	62
16	Exhaust Backpressure Schedules - Caterpillar 3208 EGR	66
17	Brake and Fuel Specific Cycle Composite Particulate and Sulfate Rates	73
18	Elemental Analysis of Filter Collected Particulate (Percent by Weight based on 47 mm Fiberglass Filter Samples)	77

LIST OF TABLES (Cont'd.)

Table		Page
19	Metals Analysis of Filter Collected Particulate (Percent by Weight Based on Fluoropore Filter Samples)	78
20	Summary of Particulate, BaP and Organic Solubles From 8 x 10 Size Glass Filter Samples	80
21	Summary of Engine Operating Conditions During 8 x 10 Size Glass Filter Tests	81
22	Composite BaP Rates	82
23	Average Odor Panel Ratings, 100:1 Dilution	85
24	Average Engine Operating Data Taken Simultaneously With Odor Ratings	86
25	Average Exhaust Analyses Taken Simultaneously With Odor Ratings	90
26	DOAS Results - Caterpillar 3208 EGR	93
27	Cycle Composite Aldehyde Rates	96
28	Cycle Composite Specific Hydrocarbons Rates	98
29	Methane Fraction of Exhaust Hydrocarbons	100
30	Evaluation Matrix	101
31	Federal Transient Smoke Cycle Opacity Caterpillar 3406	102
32	Steady-State Smoke Percent Opacity Caterpillar 3406	103
33	Gaseous Emissions by 13-Mode FTP and 21-Mode EPA Caterpillar 3406	104
34	Sulfate and Particulate Emission Rates (Based on 13-Mode Cycle) Caterpillar 3406	105
35	BaP and Organic Soluble Fraction of Particulate Collected on 8 x 10 Filter, 7-Mode Test Caterpillar 3406	106
36	Carbon and Hydrogen Content of Particulate Caterpillar 3406	107

LIST OF TABLES (Cont'd.)

Table		Page
37	DOAS Results for Caterpillar 3406 Diesel	111
38	Brake and Fuel Specific Aldehyde Rates Caterpillar 3406	112
39	Brake and Fuel Specific Hydrocarbon Rates Caterpillar 3406	113
40	Federal Transient Smoke Cycle Opacity Daimler-Benz OM-352 and OM-352A	137
41	Steady-State Smoke Percent Opacity Daimler-Benz OM-352 and OM-352A 13-Mode FTP Steady-States	138
42	Gaseous Emissions by 21-Mode EPA and 13-Mode FTP Daimler-Benz OM-352 and OM-352A	139
43	Particulate and Sulfate Emission Rates (Based on 13-Mode Cycle)	140
44	Summary of Particulate, BaP and Organic Solubles From 8 x 10 Size Glass Filter Samples Daimler-Benz OM-352 and OM-352A Engines	142
45	DOAS Results for Daimler-Benz Engines	144
46	Brake and Fuel Specific Aldehydes Rates Daimler-Benz OM-352 NA and OM-352A TC	147
47	Brake and Fuel Specific Hydrocarbon Rates Daimler-Benz OM-352 NA and OM-352A TC	148
48	Mack ETAY(B)673A With High-Pressure Injection System	151
49	Steady-State Smoke Percent Opacity Mack ETAY(B)673A with APS Pump	153
50	Gaseous Emissions By 21-Mode EPA and 13-Mode FTP Mack ETAY(B)673A with APS Pump	155
51	Mack ETAY(B)673A Sulfate and Particulate Emissions Rates - APS Pump Configuration (Based on 13-Mode Cycle)	155
52	Summary of Particulate, BaP and Organic Solubles From 8 x 10 Size Glass Filter Samples Mack ETAY(B)673A Engine	157

LIST OF TABLES (Cont'd.)

Table		Page
53	DOAS Results for Mack ETAY(B)673A With Various Injection Systems	161
54	Cycle Composite Aldehyde Rates Mack ETAY(B)673A	162
55	Cycle Composite Specific Hydrocarbon Rates Mack ETAY(B)673A	164
56	Properties of the Five Test Fuels, Contract 68-02-1777	166
57	Comparison of Gum and Boiling Range for EM-239-F and Special Distilled Cuts of EM-239-F Diesel Fuel	167
58	Federal Light-Duty Emission Standards	169
59	Average HC, CO, NO_x, and Fuel Results for Diesel- and Gasoline-Powered Oldsmobile Cutlass Cars	171
60	Average HC, CO, NO_x, and Fuel Results for Diesel- and Gasoline-Powered Volkswagen Rabbit Cars	172
61	Average Exhaust Smoke Opacity Recorded During Replicate 1975 FTP Cycles	174
62	Average Particulate Emission Rates for Diesel and Gasoline Passenger Cars	179
63	Diesel- and Gasoline-Powered Car Particulate Rate Comparison	181
64	Average Sulfate Emission Rates for Diesel- and Gasoline-Powered Passenger Cars	182
65	Comparison of Percent Sulfur in Fuel Converted to Sulfate by Gasoline and Diesel Cars	184
66	Carbon, Hydrogen, and Nitrogen Content of Filter Particulate, Percent by Weight	185
67	Metal Content of Particulate Samples (Percent of Particulate)	186
68	Listing of Average Odor Panel Ratings for Diesel-Powered Passenger Cars	188
69	Rough Comparison of Light-Duty Vehicle "D" Odor Ratings	187

LIST OF TABLES (Cont'd)

Table		Page
70	DOAS Results of Diesel Cars During Steady-State Odor Tests and Transient Cycles	192
71	Exhaust Analyses of Diesel Cars During Steady-State Odor Tests	195
72	Aldehydes Obtained During Steady-State Odor Tests and Transient Cycles	196
73	Detailed HC Analysis During Steady-State Odor Tests and Transient Cycles	199
74	Methane Fraction of Exhaust HC During Steady-State Odor Tests and Transient Cycles	200
75	BaP Content in Diesel Car Particulate Matter	201
76	Summary of Sound Level Measurements - dBA Scale	203
77	Average Acceleration Times for Diesel- and Gasoline-Powered Passenger Cars	204

I. SUMMARY

Though long appreciated by those who operate heavy-duty engines in trucks, buses, locomotives, and ships, the efficiency of the Diesel engine is also an undeniable advantage in passenger cars. Certain engine emissions from Diesels such as carbon monoxide and hydrocarbons are low relative to the uncontrolled gasoline engine. Certain other byproducts of combustion are greater than from the gasoline engine such as smoke, odor and particulate.

This project was performed in three segments, two of which dealt with heavy-duty engines used in trucks and the third with passenger cars equipped with Diesel and gasoline engines. Each segment is briefly summarized as follows.

A. Heavy-Duty Engine Characterization

Three truck engines were subjected to a series of tests to determine emission rates of unburned hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_x), aldehydes, sulfate, benzo(a)pyrene (BaP), particulate and smoke. For the two Diesel engines, odor was measured by trained panel as well as the Diesel odor analytical system (DOAS). The two Diesel engines were a 1977 Mack ETAY(B)673A, used in large intercity tractor trailer trucks and a 1977 Caterpillar 3208 equipped with an automatic exhaust gas recirculation (EGR) used in large intracity delivery trucks. A 1977 gasoline fueled Chevrolet 366 heavy-duty engine, used in the same size delivery truck as the 3208, was included for comparison. Both the Caterpillar 3208 and Chevrolet 366 were controlled to meet California emission levels. Emissions and brake specific fuel consumption were measured using the 13-mode Federal cycle as well as a 23-mode test cycle. Each comprises various combinations of engine speeds and loads and were performed on stationary engine dynamometers.

While the Mack results add to the data base of previously characterized engines, the Caterpillar 3208/EGR Diesel could be directly compared to the Chevrolet 366 gasoline. Some of the highlights were:

Regulated Gaseous Emissions - Based on the 23-mode EPA cycle composites, the Diesel CO emission rate was about one-eighth the gasoline CO emission rate. The HC emission rate was about half that of the gasoline while the NO_x emissions of the Diesel engine were about ten percent higher than the NO_x emissions of the gasoline engine. Neither the Caterpillar 3208/EGR or Chevrolet 366 were equipped with an oxidation catalyst.

Specific Fuel Consumption - The 23-mode cycle brake specific fuel consumption (BSFC) of the Caterpillar 3208/EGR Diesel was about two-thirds that of the Chevrolet 366 gasoline engines tested under comparable conditions.

Smoke - The Caterpillar 3208/EGR exhaust smoke opacity was lower by the Federal Test method than during several part power conditions of the 13-mode test such as 75 and 50 percent power at 2800 rpm. This was due to the EGR rate scheduling (some EGR at part load) while no exhaust is recirculated during the full power mode, the major condition simulated by the Federal smoke test.

Particulate - Like smoke, the Caterpillar 3208/EGR particulate rate was found to be quite sensitive to the EGR rate with part load particulate rates far above those at full power. This resulted in a 13-mode composite particulate rate of 2.96 g/kw-hr, some 3.6 times that of the Mack ETAY(B)673A and substantially higher than a two-stroke cycle GM 6V-71 HDD bus engine. Compared to a previously tested Caterpillar 3208 without EGR, the Caterpillar 3208/EGR emitted over three times the particulate. On a 13-mode brake specific particulate basis, the Caterpillar 3208/EGR produced about 12 times the particulate produced by the Chevrolet 366 HDG engine which used gasoline containing 6.06 g/ℓ (1.6 g/gal) of lead as the fuel.

Sulfate - Both Mack and Caterpillar Diesels continue to convert about on the order of 1 to 2 percent of the fuel sulfur to what is analyzed as sulfate by the barium chloranilate (BCA) method. The fuel sulfur conversions, though seemingly negligible, are based on a Diesel fuel with "National Average" sulfur content about eight times that of the "National Average" sulfur level in gasoline. Because of the presence of the lead and its byproducts of combustion, it was not possible to obtain reliable or repeatable sulfate values by the BCA method for the Chevrolet 366 engine. An alternative procedure will be necessary in the event there is continued interest in sulfate from non-oxidation catalyst equipped engines burning leaded gasoline.

Elemental Analysis - Whereas Diesel particulate is principally carbonaceous or hydrocarbon derived matter, the gasoline particulate is composed of lead and its byproducts of combustion, sulfuric acid mist and more or less carbonaceous matter, depending on combustion.

Benzo(a)Pyrene - Except for the full power-1200 rpm and a 2 percent power-2300 rpm conditions, negligible levels of BaP were measured from the Chevrolet 366 HDG engine. These two modes were sufficient, however, to make the Chevrolet 366 rate (abbreviated 23-mode cycle) to be slightly higher than the Caterpillar 3208/EGR (3.0 vs 2.5 μg/kw-hr). Difficulties were experienced using the dilution tunnel method in obtaining sufficient sample from the Chevrolet 366 engine for extraction and analysis. More experimentation is needed with this and other HDG engines to confirm the trend indicated.

Aldehydes - The Chevrolet 366 engine emitted more aldehydes overall than the Caterpillar 3208/EGR. Benzaldehyde, crotonal and formaldehyde were substantially higher.

Hydrocarbons - Compared to the Caterpillar 3208/EGR, the Chevrolet 366 emitted much more methane, benzene, and toluene. Accordingly, the non-methane hydrocarbons from the Caterpillar 3208/EGR Diesel are higher than the Chevrolet 366 gasoline engine. Methane is generally considered to be non-reactive from a photochemical point of view.

B. Engine Effects on Particulate/Sulfate

Several HDD were evaluated in various configurations to determine their effect on particulate and sulfate. The highlights are given for each experiment.

Effect of Timing

The direct injected, open chamber, Caterpillar 3406 was evaluated at three fuel injection settings; standard, 5 degrees advanced and 10 degrees retarded from standard. The major effect was to increase particulate with retarded timing. This is consistent with the well-known effect of timing retard on increasing visible smoke and reducing oxides of nitrogen. No major or obvious effects were noted on sulfate, particle size distribution, DOAS, or specific hydrocarbons. BaP and aldehydes were lowest at standard timing, highest at 5 degrees advanced timing and in between at the 10 degree retarded timing setting.

Effect of EGR

This experiment involved substantial exhaust gas recirculation directly into the inlet of the turbocharged Caterpillar 3406 engine, in the direct injected configuration. Criteria was to halve NO_x without exceeding 15 percent smoke in any mode. Like retarded timing, EGR increased greatly the total mass of particulate emitted by the engine while decreasing NO_x. Smoke was increased, CO was doubled and HC was halved with use of EGR. While particulate was increased by 2.7 times, sulfate appeared unaffected. BaP, with EGR, was cut in half while the organic soluble fraction was about the same. Particle size distribution with EGR shifted to indicate an even finer, lighter material than the same engine run in standard configuration.

Effect of Combustion System

The Caterpillar 3406 engine is produced in both the conventional open chamber, direct injected, as well as the indirect injected, prechamber, version. Thus, the experiment involved back-to-back tests on the same basic engine in the DI and prechamber configurations. The prechamber version resulted in about a 20 percent reduction in exhaust particulate, lower visible smoke and about a 40 percent increase in sulfate. The increase in sulfate is noteworthy in that this is the only such occurrence found in all experiments with this engine. CO and NO_2 were halved and substantial reductions in 13-mode FTP HC were noted. Odor ratings by the Diesel Odor Analysis System (DOAS) and specific low molecular weight hydrocarbons were also lower compared to the standard DI engine. A 7.5 percent increase in brake specific fuel consumption was found with the prechamber engine. The results of this experiment were directionally correct in light of previous experience.

Effect of Turbocharging

The pair of Daimler-Benz engines, one turbocharged and the other not, were quite similar. All turbocharged engines, however, include one or more other changes and adjustments to the engine so that the effects measured cannot be solely attributed to the turbocharger. Smoke and particulate were substantially less with the OM-352A turbocharged engine under the steady-state conditions evaluated. Particulate was about 40 percent less with the turbocharged engine, and essentially no change in sulfate was found. The turbocharged engine had lower CO and HC and higher NO_2 with slightly better cycle BSFC (about 3 percent). This behavior was anticipated from previous experience with turbocharged Diesels. No effect on particle size distribution was found. It is interesting to note that the TC engine resulted in slightly higher DOAS values of LCO, LCA and TIA. The turbocharged engine exhibited slightly higher combined low molecular weight HC, while the reverse was indicated by the 13-mode FTP HC value.

Effect of Injection System

For this experiment, the American Bosch APS high pressure injection system was compared in a back-to-back test series with the standard Robert Bosch fuel injection system. The test plan utilized the Mack ETAY(B)673A engine in its standard configuration after the 1000 hour EPA durability test, with the APS pump, and finally with a new R. Bosch standard system installed. Sulfate was little affected and a 50 percent reduction in total particulate was found. Major reductions in visible smoke and particulate were noted at 50, 75, and 100 percent power, giving essentially a "flat" smoke and particulate response versus power. NO, expressed as NO_2, was increased by 45 percent with the high pressure system, while HC and CO were little affected. Brake specific fuel consumption was improved by 4 percent. The particulate is indicated to be finer in size with the high pressure system. The substantial reduction in gross particulate by the high pressure system illustrates the need for a greater understanding of fuel injection parameters as they affect particulate production.

Effect of Fuel Residue

A brief study was made of the residual matter, common to most distillate fuels, as a cause for part of the Diesels' exhaust particulate. There is no known fuel composition parameter that defines the trace material, which has a very extended boiling range, insofar as exhaust particulate formation characteristics is concerned. A systematic and extensive laboratory/engine project is indicated to investigate and define such a relationship.

C. Evaluation of Passenger Cars Equipped with Diesel and Gasoline Engines

A fairly extensive series of evaluations were performed on a pair of Oldsmobile Cutlass and a pair of Volkswagen Rabbit passenger cars. Each pair consisted of a 1977 model powered by an emission controlled gasoline engine and a similar vehicle powered by a passenger car Diesel engine derived from a conventional gasoline engine. The Diesel, without use of an oxidation catalyst or EGR system, emits HC, CO, and NO_x that are reasonably close to 1977 standards.

Fuel Economy - Fuel economy was higher with both Diesel cars, compared to the gasoline engine counterparts. In the case of the Cutlass, fuel economy was improved by 33 percent and the Rabbit Diesel by 60 percent, based on the combined city/highway estimates. The improvements in fuel economy by the Diesel Rabbit were remarkable, with a 42.7 mpg city (+74%) and a 53.7 mph highway (+31%) estimate obtained.

Smoke and Odor - Although smoke was relatively low, it was noticeable for both Diesel-powered vehicles under certain driving conditions. Both vehicles tested emitted easily noticeable smoke during accelerations, although the duration was relatively brief. Odor levels of "D"-2.5 to 4.0 by the trained panel, at a 100:1 dilution level, represent easily noticed exhaust odor that is distinctively Diesel in character. In SwRI's opinion, this range of odor intensity would be expected to trigger substantial public reaction in the event a large number of such odor sources were to be in use in the U.S.

Particulate - Even though most of the time the two Diesel cars tested emitted smoke at or near the limit of visibility, there remains a substantial amount of particulate, on the order of 54 (Cutlass) to 82 (Rabbit) times as much as the paired vehicles powered by gasoline engines. Assuming this small sample of cars is indicative of the Diesel-to-gasoline relationship in general, then the advent of large numbers of Diesel cars may jeopardize some national and regional control strategies for reducing Total Suspended Particulate, (TSP).

Sulfate - The Diesel engines tested converted only 1 to 2 percent of their fuel sulfur content to sulfate. The vehicles equipped with oxidation catalysts and gasoline engines converted a much wider proportion of its fuel sulfur to sulfate, on the order of 1 to 17 percent, depending on the test sequence. Type 2-D Diesel fuel, according to the latest 1976 survey, is about 0.25 percent by weight sulfur. The sulfate emission test values for the experimental Diesel Cutlass were lower (10.3 versus 13.0 mg/km) and the Diesel Rabbit higher (4.0 versus 1.0 mg/km) than their gasoline engine powered counterparts.

Other Emissions - A wide variety of other unregulated emissions were measured and summarized to give information that might be used as part of a study on the potential advantages and disadvantages of the Diesel. Among the findings, the nominal 3 ± 2 percent by volume methane content of the total Diesel hydrocarbons as contrasted with the nominal 35 ± 20 percent by volume methane content of the gasoline engine hydrocarbons was interesting. Also, the inability of the dilution tunnel-glass fiber filter method to collect BaP from the two gasoline-powered cars illustrates the need for additional study.

Noise - The Cutlass equipped with the Diesel engine was noticeably louder and noisier than its gasoline engine powered counterpart. This was found during most conditions, such as the SAE J-986a driveby, as well as the exterior idle sound level measurements. When all accessories, such as the ventilation blower, were off the interior noise levels were higher for both Diesel powered cars during idle, acceleration, and cruise modes.

Performance of both Diesel cars was judged in terms of the times to accelerate at maximum rate from zero to 40 or 60 mph. The time to accelerate from 0 to 40, 0 to 60, and 20 to 60 mph was longer (the Diesel car was slower) by 20 to 27 percent as compared to the gasoline-powered Rabbit. The Cutlass, equipped with the experimental 350 cubic inch displacement (CID) Diesel engine, was 7 to 11 percent slower than the Cutlass powered by a 260 CID gasoline engine.

II. INTRODUCTION

The Diesel engine is considered by many as a potential alternative to the conventional spark-ignition engine for automobiles. Use of Diesel engines in large cars is claimed by the auto industry to be necessary to meet Congressionally mandated fleet fuel economy standards if the family size car is to be offered. In recent years, a renewal of interest in mid-range Diesels, for use in urban delivery trucks of less than 10,886 kg (24000 lbs) gross vehicle weight, has been evident. The basic reason given has been the superior fuel economy. For many years, the Diesel engine has dominated intercity trucking and both intercity and intracity buses.

A. Background

The Clean Air Act amendments of 1965 were specific in expressing concern over odor and smoke from Diesel-powered vehicles. This legislation prompted a long-range investigation of Diesel emissions which began in 1966 at Southwest Research Institute's Emissions Research Department on behalf of the Environmental Protection Agency (EPA). The long-range project resulted in a large number of reports and papers on the subject.(1-20)* A number of other studies regarding Diesel emissions were made by SwRI on behalf of EPA under separate projects.(21-34)

The original project was concerned with visible smoke and noticeable odor, both classed as "nuisance" emissions which interferred with the general welfare. Much was learned in how to measure odor and smoke and the types of conditions which would result in obvious discharges. In the intervening years, a steady broadening of this activity included unburned hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x) (now regulated emissions), methods of control and procedural development.

During the last few years, an increasing variety of non-regulated materials in Diesel exhaust have come under scrutiny.(35) Measurement of sulfur dioxide (SO_2) and several other emissions have been investigated in an attempt to quantify emissions for which little data was available.

It is important to know as much as possible about the advantages and disadvantages of an alternative to the conventional gasoline engine as well as to document the emission rates from Diesel engines and Diesel-powered vehicles.

B. Objective

The project had several tasks but with one objective--to characterize and compare exhaust emissions from a variety of vehicles and engines. One task dealt with three heavy-duty engines, (two Diesels, and one conventional SI powerplant). One of the Diesel engines was a mid-range size to which the gasoline engine could be more directly compared.

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* Superscript numbers in parentheses designate References at end of this report

Another task was investigation of major engine changes on particulate and sulfate emissions from Diesel engines. Such engine variables as fuel injection timing, turbocharging, exhaust gas recirculation (EGR), direct versus indirect injection, and injection characteristics were studied.

The final task was to evaluate and compare Diesel-powered passenger cars, derived from gasoline engines for a wide variety of unregulated exhaust emissions. Also, the regulated emissions, fuel economy, noise and acceleration performance was obtained and compared.

C. Publication/Presentation

Section VI of this report deals with the emissions evaluation of four passenger cars, two Diesel-powered and two gasoline-powered. This portion of the project was summarized in Society of Automotive Engineers Paper No. 770818 titled "Emissions From Diesel Versions of Production Passenger Cars."(36) It was presented during the September 26-30, 1977 Passenger Car Meeting in Detroit, Michigan. On May 18, 1978, a presentation titled "What You Always Wanted to Know About Diesel Particulate (but were afraid to ask)," was made by Karl Springer at the EPA Symposium on Diesel Particle Emissions Measurement and Characterization held in Ann Arbor, Michigan. This presentation included emission rates for both light-and heavy-duty engines from this project.

D. Acknowledgement

The Environmental Protection Agency selected and furnished the four LDV's evaluated. The cars were provided to EPA for the SwRI test program through the courtesy of the respective manufacturers. They were Volkswagen of America and Oldsmobile Division of General Motors. Appreciation is also expressed to Caterpillar Tractor Company, Mack Trucks, Inc., American Bosch Corporation, and General Motors Corporation for use of engines and experimental hardware during the heavy-duty engine evaluations. Without the assistance, guidance and cooperation of staff members of these companies, this project could not have been performed.

III. DESCRIPTION OF ENGINES, VEHICLES, FUELS, AND PROCEDURES

This section describes the test engines and vehicles, fuels and their selection, test plan and procedures followed.

A. Heavy-Duty Engines

Table 1 lists particulars that describe the six heavy-duty engine configurations studied.

1. Three Engine Characterization

The first three engines listed on Table 1 (Mack, Caterpillar, and Chevrolet) were used for emissions characterization. The Mack ETAY(B)673A and Caterpillar 3208 were both HDD engines that has already performed a 1000 hour durability test as a part of the EPA gaseous and smoke emission certification program. As such, the engines were prototype 1977 models.

The Mack engine features a 1900 rpm rated speed (instead of 2100 rpm) for improved fuel economy, a rated power of 235 kw (315 hp) with peak torque at 1450 rpm. Since Mack desired to perform some laboratory analysis of the fuel injection lines from the 1000 hour durability engine, new fuel lines were furnished and installed. Also, at Mack request, the fuel injectors were removed, inspected, and bench tested to assure their satisfactory operation and then replaced in the engine. Otherwise, no changes were made.

The Mack engine used an air-to-air intercooler for cooling the turbocharger compressor output air flow prior to its entering the engine. The cooling air was blown over the heat exchanger by means of a tip-turbine powered by compressor bleed air. This is the first heavy-duty production Diesel engine to use this method of increasing charge density.

The Caterpillar 3208 engine was rated at 149 kw (200 hp) at 2800 rpm. It was a prototype of 1977 California production and featured a modulated exhaust gas recirculation (EGR) system to meet the 1977 California nitric oxide (NO) expressed as nitrogen dioxide (NO_2) plus hydrocarbon (HC) standard of 6.7 g/kw-hr (5 g/bhp-hr). This is the first production Diesel engine to utilize EGR as an emission control method.

The Chevrolet 366 engine was selected to represent a popular, alternative type of powerplant used in 2-axle trucks of 7258 - 10,886 kg (16,000 - 24,000 GVW) and urban type 2-axle tractors. In many such applications, the Chevrolet 366 or comparable size gasoline heavy-duty engines are used, with a mid-range Diesel, of the Caterpillar 3208 size, offered as an alternative. Therefore, the Chevrolet 366 and Caterpillar 3208 results can be directly

TABLE 1. DESCRIPTION OF HEAVY-DUTY DIESEL ENGINES

Engine Make	Mack	Caterpillar	Chevrolet	Caterpillar	Daimler-Benz	Daimler-Benz
Engine Model	ETAY(B)673A	3208	366	3406$^{(d)}$	OM-352	OM-352A
Engine Serial No.	6F4310	1A6076	19645-72C	1A5484	(935-10-125488)	S/N935-10-01-9653
Strokes/cycle	4	4	4	4	4	4
Cylinder arrangement	I-6	V-8	V-8	I-6	I-6	I-6
Displacement, liters	11.01	10.42	6.0	14.63	5.67	5.67
cubic inches	672	636	366	893	346	346
Compression ratio	14.99	16.5:1	7.6:1	14.5:1(16:1)	17.0	16.0
Type Aspiration	TC$^{(a)}$	NA$^{(a)}$	NA$^{(a)}$	TC$^{(a)}$	NA$^{(a)}$	TC$^{(a)}$
Rated Speed, rpm	1900	2800	4000	2100	2800	2800
Power at rated speed, kw	235	149	138$^{(c)}$	242	96	108
hp	315	200	185$^{(c)}$	325	129	145
Peak Torque Speed, rpm	1450	1400	2800	1200 (1400)	2000	1800
Peak Torque, N-M	1423.8	617	394$^{(c)}$	1375 (1319)	361	415
lb-ft	1050	455	290$^{(c)}$	1011 (970)	266	306
Typical Application	IC$^{(b)}$	U$^{(b)}$	U$^{(b)}$	IC$^{(b)}$	U$^{(b)}$	U$^{(b)}$
Typical Fuel Type	DF-2	DF-2	Gasoline	DF-2	DF-2	DF-2

(a) TC-Turbocharged, NA - Naturally Aspirated

(b) IC-Intercity Truck,Tractor, U - Urban Truck and Truck-Tractor

(c) Single Exhaust Version

(d) Items in ( ) are for the IDI PC configuration compared.

The specific Chevrolet 366 evaluated was the California version. It featured EGR and air injection but no oxidation catalyst. It was intended to operate on regular grade leaded motor gasoline.

2. Sulfate/Particulate Study Engines

Table 1 also describes three Diesel engines used, along with the Mack engine, in the investigation of engine parameters on sulfate and particulate. The Mack ETAY(B)673A engine was used in standard and high pressure fuel injection configurations. The Caterpillar 3406, a turbocharged engine, was run as a direct injected open chamber and as an indirect injected, prechamber, combustion configuration. In addition to varying start of injection timing, EGR was performed using a manual control system as a part of the range of variables investigated. The two Daimler-Benz engines are as close to being identically designed engines as available with the major difference one of turbocharging. It should be recognized that there is no such thing as running an engine with and without turbocharger and have the resulting engine operation indicative of normal design. Invariably, the injection pump curve and fuel delivery characteristics are modified even when the compression ratio and maximum power are undisturbed.

An example of such turbocharger application was the turbo-kit for Cummins NH 250 naturally-aspirated engines. This retrofit kit was intended to reduce visible smoke and by lightly turbocharging, was effective in doing so. A fleet test of three such conversions is described in Reference 13. The maximum fuel rate and maximum power was unchanged yet the pump had a different torque curve (fuel rate versus speed) to match the turbocharger.

The OM-352 and 352A are described in Table 1. Both 6-cylinder engines have identical 97 mm bore, 128 mm stroke and displacement of 5.67 litres (346 CID). The compression ratio was lower for the OM-352A, the engine fitted with a turbocharger. Although both engines have identical rated speeds, the rated power was a bit higher and the peak torque speed lower for the OM-352A. Use of these two engines was not necessarily the best way to determine the effect of turbocharging but was the best selection available to this project within the time and funding available.

B. Light-Duty Vehicles

The four light-duty test vehicles are described on Table 2. The cars are grouped in pairs, a Diesel- and gasoline-powered Oldsmobile Cutlass and a Diesel- and gasoline-powered Volkswagen Rabbit. Note that the Oldsmobile Diesel was an experimental engine derived from a 350 cubic inch displacement (CID) or 5.74 litre gasoline engine. Please refer to References 37-39 for additional description of the VW Rabbit Diesel. References 40 and 41 describe the Diesel version of the Oldsmobile 350 engine.

For comparison purposes, a 4.26 litre (206 CID) gasoline engine was used. This vehicle was subject to the 1977 Federal Emissions Standards. This smaller displacement engine was selected to give a comparison based on a more

TABLE 2. DESCRIPTION OF LIGHT-DUTY TEST VEHICLES

	Cutlass		Rabbit	
	Diesel	Gasoline	Diesel	Gasoline
Model Year	1976	1977	1977	1977
Vehicle ID	3J29R6M181269	3J57F7R115286	1763188714	1763096846
Vehicle Size	Mid-Size	Mid-Size	Subcompact	Subcompact
Number of Doors	2	2	2	2
Number of Passengers	5	5	4	4
Odometer, km	21988	4562	3686	7020
Number of Cylinders	V-8	V-8	I-4	I-4
Displacement, litres	5.74	4.26	1.47	1.59
Bore, mm	103.0	88.9	76.5	79.5
Stroke, mm	85.98	86.0	80.0	80.0
Compression Ratio	22.7:1	8.0:1	23.5:1	8.2:1
Output Power, kw	(a)	82.1	35.8	53.0
at rpm		3400	5000	5600
Transmission Type	Auto	Auto	Man	Man
Speeds	3	3	4	4
Rear Axle Ratio	2.41:1	2.73:1	3.90	3.90
Tire Size	ER78-14	ER78-14	155SR13	155SR13
Vehicle Weight, kg				
Empty (Scale)	1955	1814	885	885
Test (Inertia)	2041 (4500 lbs)	2041 (4500 lbs)	1021 (2250 lbs)	1021 (2250 lbs)
Road Load, kw[b]				
at 80.5 km/hr	9.47	9.47	5.45	5.45
Catalyst Equipped	No	Yes	No	Yes
Air Injected	No	No	No	No
EGR Equipped	No	Yes	No	Yes
Fuel Injected	Direct	No	Direct	Manifold[c]

(a) not available

(b) no air conditioning allowance in Road Load

(c) Bosch K-Jetronic

equivalent power to vehicle weight basis. The gasoline-powered 1977 Rabbit was the manifold fuel injected version and incorporated emission control technology to meet the 1977 California standards.

C. Test Fuels and Lubricants

Table 3 lists the inspection results of two Diesel and two gasoline test fuels used.

1. Heavy-Duty Engine Test Fuels

The Mack ETAY(B)673A engine was tested using EM-239-F, a commercially available name brand Diesel fuel. The Caterpillar 3208 engine was tested on EM-272-F, a newer batch of the same type 2D Diesel fuel as used with the Mack engine. The fuel properties of both fuels are fairly similar as may be noted from Table 3. The properties of both test fuels compare well with the arithmetic average of the 1973 Bureau of Mines Survey(42) and the arithmetic average of the 201 samples included in the five region 1976 survey by the Energy Research and Development Administration (ERDA)(43) listed in Table 4.

Note that the Bureau of Mines fuel properties are not sales-weighted due to the unavailability of such information. Therefore, they must be used with caution if a true national average is to be obtained from the data.

Although fuel survey data for 1973 (published in 1974) were used as the basis in searching for a "National Average" No. 2 fuel, data in Table 4 show that no major shifts in properties occurred between the 1973 and 1976 fuels surveyed. In general, the more recent fuels show slightly higher density, sulfur, cetane, and boiling range. Comparing the No. 2 fuel survey results to EM-239-F and EM-272-F shows no significant differences between them.

The sulfur content in both EM-239-F and EM-272-F fuels were increased by adding ditertiary butyl disulfide. The EM-239-F fuel was adjusted to 0.23 percent value, consistent with the then available 1973 survey results of 0.228 percent by weight. The later batch, EM-272-F, was adjusted to essentially the same level, 0.235 percent by weight, to be consistent with EM-239-F.

Incidentally, EM-239-F was used in two other major projects for EPA. One such contract (68-02-1777) was a five-fuel, two-engine (HDD) emissions characterization.(35) The other contract was a five-fuel, 2-passenger car (LDD) characterization of emissions(44) for EPA which was a companion project to 68-03-1777.

All other HDD engines (Caterpillar 3208 EGR, 3406, Daimler-Benz OM-352 and 352A engines) were run on EM-272-F. Operation of the Mack ETAY(B)673A engine with and without the high pressure injection system was made with EM-272-F.

The Chevrolet 366 engine was run on EM-275-F, the last fuel listed on Table 3. At the request of the Project Officer, a leaded regular grade commercial gasoline of lead content of 1.5 to 2 g/gal (preferrably near 1.5), was used. Survey data of 10 name brand gasolines in the San Antonio area, performed

TABLE 3. DESCRIPTION OF TEST FUELS

Property	ASTM	Diesel Fuels		Gasoline Fuels	
Source		Gulf	Gulf	Gulf	Howell
Type		2-D	2-D	Unleaded	Leaded
Code		EM-239-F	EM-272-F	EM-237-F	EM-275-F
Gravity, °API	D287	36.1	37.0	59.9	54.2
Density, g/ml (lb/gal)		0.844(7.043)	0.840(6.933)	0.738(6.154)	0.7347(6.130)
Viscosity @ 100°F Kinematic, CS	D445	2.66	2.50		
Sulfur Content, wt. %	D1266	0.23	0.235	0.031	0.030
Cetane Number	D976	48.7	50.2		
Distillation Temp., °C (°F) Vol. Recovered	D86				
IBP		186(366)	164(328)	32(89)	37(98)
10%		216(421)	211(411)	52(125)	66(150)
50%		257(494)	259(499)	103(217)	104(220)
90%		303(578)	303(578)	170(338)	143(290)
End Point		337(640)	338(641)	211(412)	171(340)
FIA, %	D1319				
Aromatics		21.6	23.0	26.4	49.9
Olefins		0.8	1.14	2.9	5.2
Saturates		77.6	75.8	70.7	44.9
Flash Point, °C (°F)	D93	87(189)	68(155)		
Lead, g/l (g/gal)	D3237			<0.0189(<0.005)	6.06(1.6)
Phosphorus, g/l (g/gal)	D3231			0.0034(0.0009)	0.0004(0.0001)
RVP, kPa (psig)	D323			62.74(9.1)	51.71(7.5)
Research Octane	D656			92.0	91.5

TABLE 4. "NATIONAL AVERAGE" PROPERTIES FROM FUEL SURVEYS

Property	ASTM	BM Diesel Survey 1973 (42)	BM Diesel Survey 1976 (43)
Source			
Type		2-D	2-D
Code			
Gravity, °API	D287	36.4	35.7
Density, g/ml (lbs/gal)			
Viscosity @ 100°F			
Kinematic, CS	D445	2.67	2.73
Saybolt Univ., sec	D88	34.9	35.1
Sulfur Content, wt %	D129 D1266	0.228	0.253
Aniline Point, °C (°F)	D611	(145.5)	(145.2)
C Residue on 10%, wt %	D524	0.102	0.105
Ash, wt %	D482	0.001	0.008
Cetane Number	D613	47.9	48.3
Distillation Temperature, °C (°F)			
Volume Removed	D86		
IBP		189(373)	190(374)
10%		219(426)	222(431)
50%		257(495)	262(503)
90%		302(575)	308(586)
End Point		327(620)	334(633)
Flash Point, °C (°F)	D93	66(150)	----

in the fall of 1976, indicated lead levels of 1.64 to 2.49 g/gal, most above 2 g/gal. A sample of one name brand taken on April 5, 1977 showed 2.48 g/gal even though earlier data showed it to be within the desired range.

This experience indicated that the only way to obtain the desired level of lead and octane was to obtain a special blended fuel from Howell Hydrocarbons, a local refiner-blender. The sulfur level in this fuel was adjusted to 0.03 percent by weight through the addition of thiophene. The 0.03 percent fuel sulfur level is taken to be the "National Average" for regular grade gasoline.

2. Light-Duty Vehicle Test Fuels

Both LDD cars were evaluated using EM-239-F, the fuel used with the initial series of Mack ETAY(B)673A tests. This fuel was discussed in the previous subsection and its inspection data listed on Table 3.

Table 3 also lists the gasoline inspection data for the fuel used with both gasoline-powered cars. EM-237-F is a regular grade, commercially available unleaded motor fuel which had its sulfur content increased to 0.03 percent by weight by the addition of thiophene.

3. Lubricants

Each heavy-duty engine was filled with crankcase oil that met the specifications of the engine manufacturer. Shell Rotella T-30 wgt was used in the Mack ETAY(B)673A, while Texaco URSA Series 3 - 30WSAE was used in both Caterpillar and both Daimler-Benz engines. Texaco Havoline 30SAE HD was used in the Chevrolet 366 gasoline engine. All vehicle tests were run using the oil that was in the crankcase as received.

D. Test Plans

The test plans are described briefly for each category of engines/vehicles evaluated.

1. Heavy-Duty Engines

The HDD engines were operated on eddy current type stationary engine dynamometers of 373 kw (500 hp) capacity. This permitted acquisition of test data that may be related to the Federal Test Procedure (FTP) for heavy-duty Diesel engines by the 13-mode test for gaseous emissions and the Federal smoke test for visible emissions. Thus, the data can be compared to Federal limits for HC, CO, NO (as NO_2) and smoke. The nonregulated pollutants could then also be expressed in units consistent with this test; namely, grams per kilowatt-hour.

The gasoline engine was run on a similar type stationary dynamometer with 187 kw (250 hp) capacity. In the case of the Chevrolet 366 and Caterpillar 3208 engines, motoring capability was added to permit operation under closed throttle conditions.

The test procedure followed was the EPA 23-mode experimental test cycle (23-mode EPA), which includes the 11 different modes of the 13-mode FTP for HD engines. This procedure is described in a later subsection.

Each series of tests began with the running of several, replicate, 23-mode EPA gaseous emission tests followed by several Federal smoke tests in the case of the Diesel engines. From this, the general performance of the engine could be assessed in terms of fuel consumption, air consumption and power output. The engine's smoke level and HC + NO_2 level were then compared to standards and to previous data run either at SwRI or by the manufacturer. The next step in the series was to connect the exhaust to the dilution tunnel via a suitable muffler so that only a portion of the exhaust was diluted and the remainder vented. The dilution tunnel runs were based on the 11 different modes of the 13-mode test and involved replicate runs for 47 mm fiberglass and Fluoropore and 203 x 254 mm (8 x 10 inch) size fiberglass filters.

Sulfur dioxide, sulfate, polynuclear aromatic hydrocarbons (PNA), as well as particulate emission rates, were then determined. The engine exhaust was then connected to the SwRI odor sampling dilution system for odor panel rating. During these replicate days of operation on each engine configuration, odor panel ratings, Diesel Odor Analytical System (DOAS) measurement, non-reactive hydrocarbons (NRHC) and aldehydes were measured as well as HC, CO, NO_x, CO_2 and selected engine parameters. No odor measurements were taken with the gasoline engine since the odor panel was only trained to evaluate Diesel exhaust.

The test plan was somewhat abbreviated for the Caterpillar 3406, the two Daimler-Benz engines, and the retesting of the Mack engine. The major emphasis for these experiments was on sulfates, particulates, smoke and regulated emissions and engine parameter effects.

2. Light-Duty Vehicles

The four cars were tested as a group in their as-received condition beginning with replicate cold start urban driving cycle tests in accord with the 1975 Federal Test Procedure (FTP), sulfate emission test (SET) by the congested freeway cycle, and then by the highway fuel economy test (FET). Gaseous tailpipe emissions of unburned hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x) as well as fuel consumption/economy by the carbon balance method were obtained. Measurement of detailed low molecular weight hydrocarbons, aldehydes, and Diesel odorant groupings by the Diesel Odorant Analytical System (DOAS) were made during selected transient cycles.

Next, smoke tests were made using the EPA full flow light extinction smokemeter of the two Diesel cars during repeat runs of the three transient driving cycles used in the FTP, SET, and FET. The entire exhaust was then directed into a dilution tunnel and a third series of FTP, SET, and FET driving cycles performed to obtain emission rates of particulate and sulfate. A fourth series of tests were then made to obtain larger particulate quantities for indication of benzo(a)pyrene (BaP).

The two Diesel-powered vehicles were then operated on a dynamometer adjacent to the odor measurement room and replicate odor evaluations made by the trained panel method. Aldehydes, DOAS, CO, carbon dioxide (CO_2), HC, and NO_x measurements were obtained at the same time for correlation and definition purposes.

Finally, all four vehicles were subjected to vehicle/engine sound level measurements and a series of wide-open throttle (WOT) accelerations. With the exception of odor and smoke, the two gasoline-powered vehicles were evaluated in every category.

E. Procedures and Analysis

The test procedures and analysis systems used for each emissions category are described in the following subsections. In every case possible, recognized procedures published in the Federal regulations were employed. Instruments, sampling and analysis, and other facilities adhered strictly to these methods without exception. Where a Federal procedure did not exist, existing procedures for HDD vehicles were modified or adapted as necessary for purposes of this project. The advice and consent of the Project Officer was obtained on those areas of substantial modification before proceeding.

In general, the procedures and analytical efforts are the same as that used in previous projects in the long range Diesel emissions investigation. The specific test and analytical procedures have been described in some detail in earlier papers (4,9,17,18) and reports.(1,14,18) Therefore, the description of test procedures will be in summary form and limited to the most pertinent items for each category.

1. EPA 23-Mode HD Test

The EPA 23-mode test was selected for gaseous emissions measurements of the Mack ETAY(B)673A, Caterpillar 3208, and Chevrolet 366 engines. These engines comprised the HD emissions characterization portion of the project; and thus, a test procedure compatible to both Diesel and gasoline HD engines was used. Appendix A is a copy of the test procedure, originally prepared by EPA as an improvement to the then and still current 9-mode FTP for gasoline HD engines and the 13-mode FTP for Diesels. The test procedure has been used in various EPA projects(45-47) since its development by EPA.

The test is, like the 13-mode and 9-mode procedures, an engine map, but includes more test points and weighting factors based on the initial Ethyl Truck and Bus Survey(48) performed in 1963. For Diesel engines, the two speeds are as defined by the 13-mode FTP, namely, rated and 60 percent of rated or peak torque (whichever is higher). For gasoline engines, the two operating speeds, other than curb idle, were 1200 and 2300 rpm. Instrumentation improvements included the use of heated flame ionization, instead of non-dispersive infrared (NDIR) for hydrocarbons (HC) and chemiluminescence (CL) for oxides of nitrogen (NO_x). The CL instrument for NO_x replaced NDIR nitric oxide (NO) measurements for both Diesel and gasoline, whereas only gasoline engines were affected by the change to the heated flame ionization detector (HFID) for hydrocarbons.

2. 13-Mode FTP HD Test

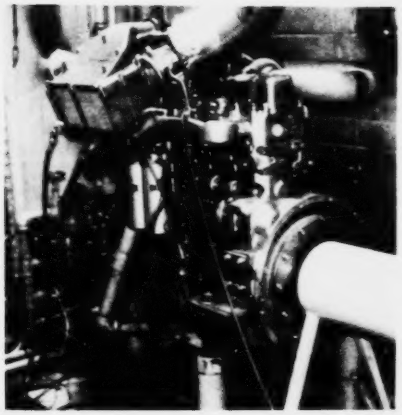
The 1974-1978 13-mode FTP is described in Reference 49 as a 130-minute long speed load map of 13 modes, 10 minutes per mode. In addition to CO and NO by NDIR (According to SAE recommended practice J-177), air rate must be measured continuously (according to SAE recommended practice J-244). A Flo-Tron system was used to measure the net fuel consumption of the engine. Exhaust hydrocarbons were measured by heated, 191°C (375°F), flame ionization detector optimized in accord with SAE recommended practice J-215. The procedure starts with low idle, then 2, 25, 50, 75, and 100 percent load at intermediate speed followed by low idle. Then speed is increased to "rated" at 100 percent load with decreases to 75, 50, 25, and 2 percent. Another idle is then run. This procedure was used on the Caterpillar 3406, Daimler-Benz OM-352 and 352A engine and evaluation of the high pressure injection system on the Mack engine. Thirteen-mode FTP emissions were also computed from the EPA 23-mode test modal results even though the time in mode is shorter and the sequencing (history) is different.

The 13-mode test points were used as the basis for all particulate, sulfate and related emissions for all HD engines tested. To this were added the motoring modes for the Chevrolet 366 and Caterpillar 3208. Seven modes of the 13-mode test were used for odor and BaP analyses. More on these abbreviated test cycles will be discussed in later subsections. The important feature is the modal testing nature of the HD engines being expanded or abbreviated versions, basically, of the 13-mode FTP. In Figure 1 are photographs showing each of the six HD engines (five Diesel and one gasoline type) investigated. The air-to-air intercooler used with the Mack engine is shown in the supper left photo. The EGR system for the Caterpillar 3208 is illustrated in the upper right photo. The 50 hp electric motor used for the motoring modes is shown in the center left picture. The 50 hp dynamometer is shown in several of the photos.

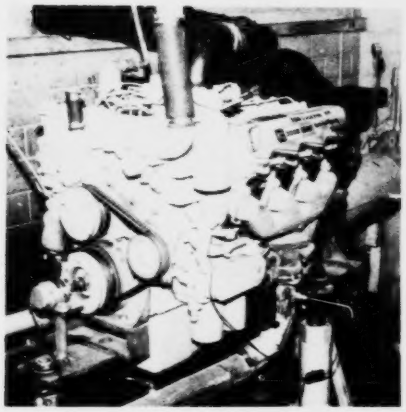
3. Light-Duty Vehicle Transient Cycles

The cold start 1975 FTP was the basic gaseous transient procedure used for the four LDV's. It is essentially the same for both gasoline and Diesel fueled cars. The basic gasoline fueled vehicle procedure was described by Reference 50 and modified in more recent Federal Registers. The Diesel procedure was originally described in Reference 51 and modified in later Federal Registers. Hydrocarbon values for the two Diesels were obtained by the continuous hot flame ionization analysis.(9) In practice, two complete 23 minute urban dynamometer driving schedule (UDDS), the first from a cold start and the second after a 10 minute soak, were performed. This allowed sufficient sample time for particulate, sulfate, and other unregulated emissions. No evaporative hydrocarbon tests were made.

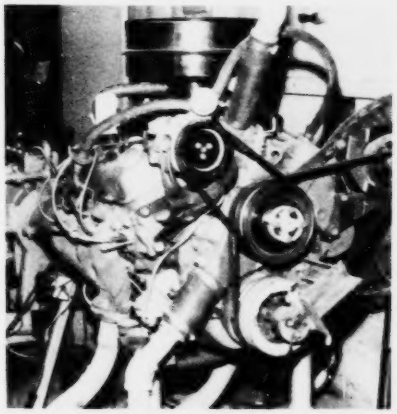
Two other test cycles were utilized. Each represents a higher average speed and overall power level. The congested freeway driving schedule (CFDS)(52) is 21.7 km, 23.3 minute, procedure of 56.0 km/hr average speed. It is run from a hot start and represents the type of driving considered typical of maximum sulfate emissions. Originally called the sulfate emission test or SET cycle, this test cycle was employed with all four cars.



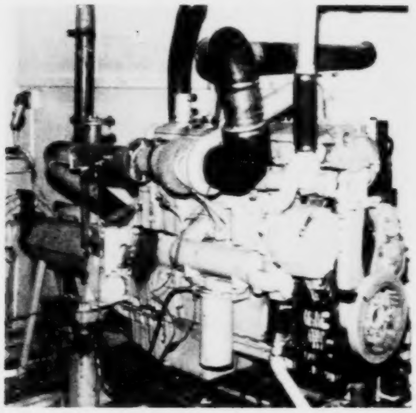
Mack ETAY(B)673A



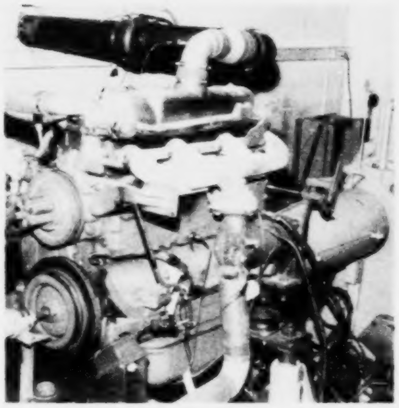
Caterpillar 3208/EGR



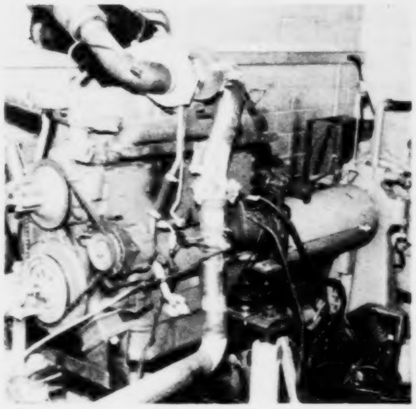
Chevrolet 366



Caterpillar 3406



Daimler-Benz OM-352



Daimler-Benz OM-352A

Figure 1. Stationary Test of Heavy-Duty Diesel and Gasoline Engines

The last of the three transient cycles was the highway fuel economy test(53) or FET. This schedule is of 12.8 minutes length, is from a running hot start, and is 77.6 km/hr average over a 16.48 km cycle. In practice, the cold 23 minute UDDS was followed by the hot 23 minute UDDS and then by an SET and finally an FET. A 10 minute soak (engine off) was observed between each cycle. Figure 2 shows a speed-time trace for all three test cycles for a general comparison.

In addition to the usual HC, CO, and NO_x measurements, samples were continuously taken and collected in reagents for wet chemical analysis or in suitably packed traps for later odor analysis. These samples were withdrawn in the stainless steel pipe section connecting the exhaust dilution point (below the CVS filter box) and the CVS inlet. Several probes were inserted into this pipe section--one probe for the DNPH bubblers and one for each of the three odor trapping systems for the Diesel Odor Analytical System (DOAS).

These probes were located adjacent to the probe used to obtain the continuous HC sample. All sample lines and interfaces were heated as required to maintain sample integrity for Diesels. HC sampling and Diesel odor analytical systems (DOAS) traps were taken at gas temperatures of 191°C (375°F). Aldehyde samples were obtained by use of large glass bubblers immersed in ice water.

A digital integrator was used to integrate the time-concentration signal from the Diesel HC analyzer, a flame ionization detector with linear response. The other continuous samples depended on their absorbing materials, reagent for wet collected samples, and chromosorb in the case of the Diesel odor traps to integrate a total representative sample for the entire 1975 FTP.

In the case of wet collected and odor traps, the entire 23 minute (Bags 1 and 2) and the third bag 505 second portion of the 1975 FTP were taken in a single collector (bubbler or trap). This was necessary to obtain sufficient sample for analysis and preclude the problem of switching after the first 505 seconds of the run (cold start bag).

Figure 3 also shows various views of the test set-up used with the four cars tested by the three transient procedures. The driving aid strip chart and variable inertia system are shown in the center left photo. The engine cooling fan and chassis dynamometer are shown in the upper left and center right photo. The lower two photos of Figure 3 are the two gasoline cars under test. Note the CVS located behind the car in the lower right view.

4. Smoke Test Procedures

Smoke tests were performed on both heavy-duty and light-duty engines as follows.

a. 1974 HDD Smoke FTP - HD Engines Only

The Federal smoke test, promulgated in 1968(54), was the basic smoke evaluation procedure utilized for the five HD engine configurations. It was improved and more stringent standards adopted in 1972(50) for 1974

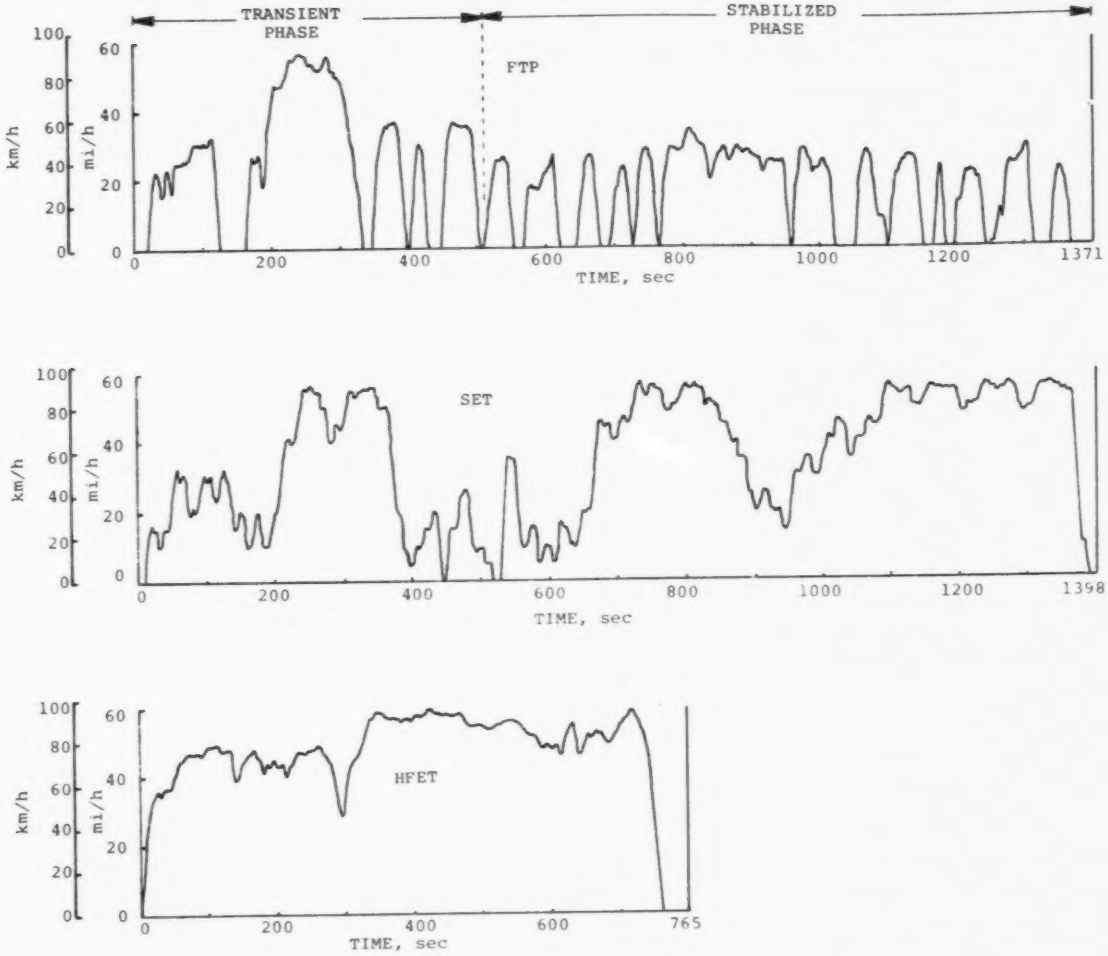
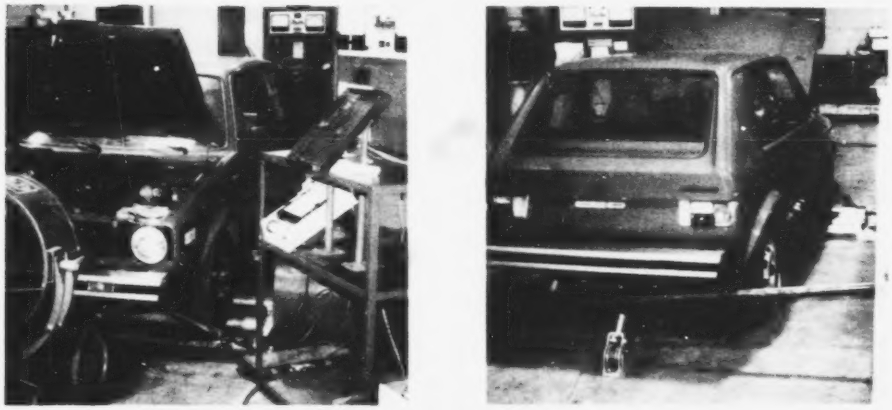
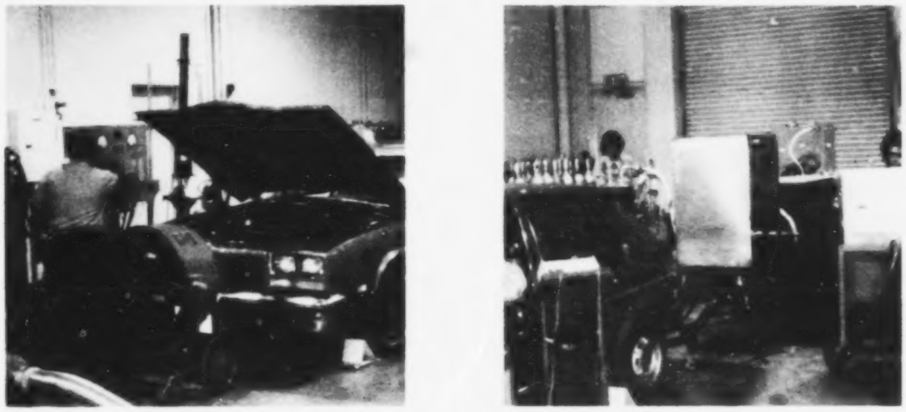


Figure 2. Speed Versus Time Traces of FTP, HFET, and SET-7 Driving Cycles

1976 Oldsmobile Cutlass, Diesel-Powered



1977 Volkswagen Rabbit, Diesel-Powered



1977 Oldsmobile Cutlass-Gasoline

1977 Volkswagen Rabbit-Gasoline

Figure 3. Oldsmobile and Volkswagen Diesel- and Gasoline-Powered Passenger Cars Under Test

certification purposes. Replicate smoke tests were made using the Federal HD smoke test, shown in the Figure 4 schematic. It consists of an initial engine acceleration from 150 to 250 rpm above the low idle speed to 85 to 90 percent of rated engine speed in 5.0±1.5 seconds, a second acceleration from peak torque speed (or 60 percent of rated speed, whichever is higher) to 95 to 100 percent of rated speed in 10.0±2.0 seconds, and (following this second acceleration) a full-power lugdown from 95 to 100 percent of rated speed to the particular intermediate engine speed (peak torque speed or 60 percent of rated speed) in 35.0±5 seconds. Three of these sequences constitute one smoke test.

For each sequence, the average smoke opacity from the 15 highest-valued, one-half second intervals of the two accelerations determines the "a" factor, and the average opacity from the five highest-valued, one-half second intervals of the lugdown mode determines the "b" factor. The maximum values allowed for "a" and "b" factors of 1970 through 1973 certification engines were 40 and 20 percent opacity, respectively. For 1974, the "a" factor was reduced to 20 percent opacity and the "b" factor was reduced to 15 percent opacity. The peak or "c" factor, which is the average of the three highest one-half second intervals per cycle, is determined from the "a" and "b" chart readings. The three cycle "c" values are then averaged to determine the "c" factor for the test.

Smoke was also measured during full power and during the 13-mode test sequence. These full-power and modal smoke values give additional insight on steady-state smoke performance and provide 13-mode smoke opacities for possible correlation to 13-mode particulate results.

b. Transient Smoke Tests - LDV's Only

There is currently no recognized U.S. smoke test procedure for LD passenger car exhaust. Although the HD schedule of speed and load versus time can be used with the LD vehicle by a chassis dynamometer version of the test, it is uncertain whether this test is indeed representative of the way the smaller, higher speed Diesels operate. Specifically, engine rated speed is considered higher than that normally encountered in passenger cars in urban use. The visible smoke emissions from the two Diesel LDV's were continuously recorded during operation of the vehicle over the three transient cycles (FTP, SET, FET) but with the CVS disconnected.

The two top photos of Figure 5 show the two Diesel cars as prepared for the smoke tests. Note the short 0.61 meter (24 inch) exhaust pipe extension of 50.8 mm (2 inch) exhaust pipe. The EPA smokemeter is mounted at the end of this pipe so that the centerline of the light beam is 127 mm (5 inches) from the tip of the pipe. The usual LD water brake Clayton 50 hp chassis dynamometer with belt drive inertia system was employed. The multi-pen strip chart recorder was used to monitor smoke opacity, vehicle and/or engine speed. The usual driving aid was used to drive the transient UDDS, SET (CFDS), or FET speed versus time trace. The same type smokemeter was used with the exhaust from stationary operated HD Diesel engines with the exception that the exhaust pipe diameter was larger, in accord with the Federal Register.

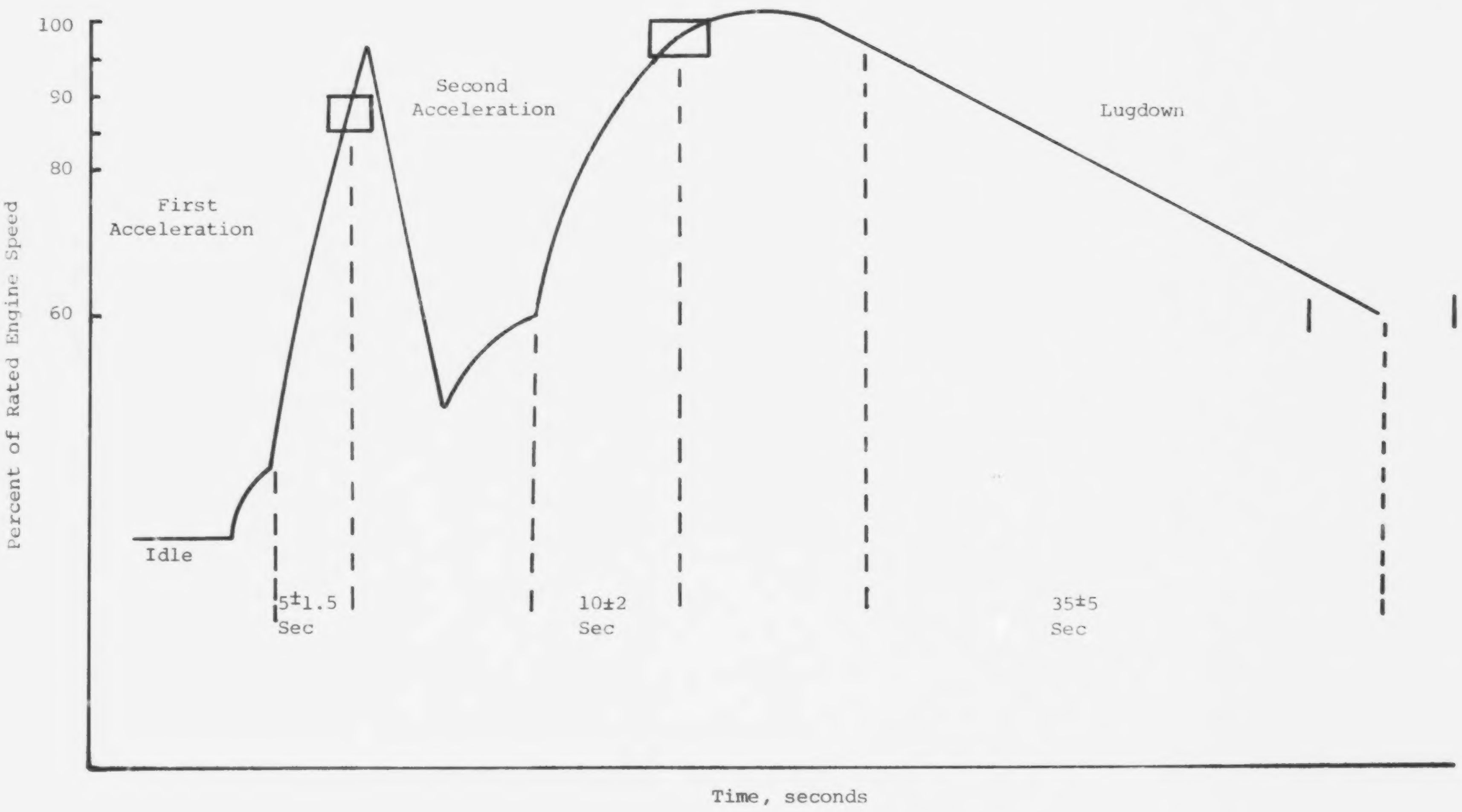
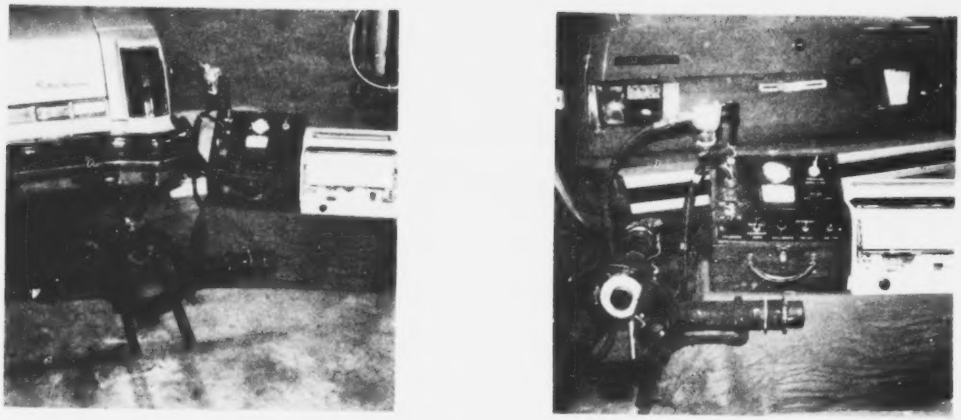
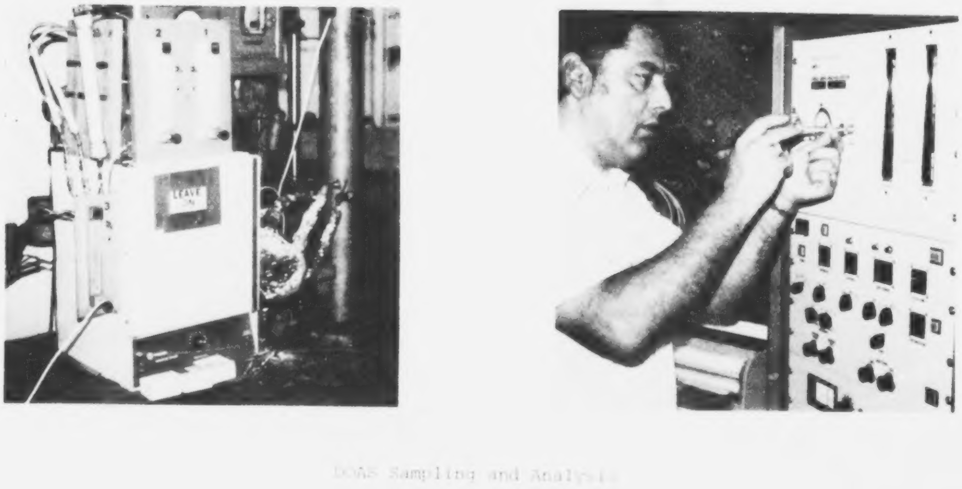


Figure 4. Schematic of One Cycle of Federal Smoke Compliance Test
Engine Speed Versus Time



EPA Smokemeter Employed with Diesel-Powered Cars

EPA Q/I Diesel Odor Kit and Trained Odor Panel



DOAS Sampling and Analysis

Figure 5. Smoke and Odor Measurement Equipment

5. Odor and Related Instrumental Analyses - HD and LDV Engines

This subsection includes evaluation of odor by trained panel--the measurement of gaseous emissions and trapping-analysis of odor samples by the DOAS simultaneously with odor measurements.

a. Evaluation by Trained Panel

The EPA (PHS) quality-intensity (Q/I) or Turk kit method of evaluation of dilute samples of Diesel exhaust odor(55) was employed to express odor judgments by the trained ten-person SwRI odor panel. The kit, shown partially in Figure 5 (center left photo), includes an overall "D" odor in Steps 1 through 12 (12 being strongest) that is made of four sub-odors or qualities. These comprise burnt-smoky "B", oily "O", aromatic "A", and pungent "P" qualities, each in a 1 through 4 intensity series (4 being strongest). Special odor sampling, dilution, and presentation facilities(1,2) for Diesel odor research were developed ten years ago using design criteria obtained in field studies of atmospheric dilution of bus and truck exhaust.

From the Diesel odor opinion survey conducted in 1970(24,25), it was found that 58 percent found odor objectionable at "D"-2, 81 percent found the odor objectionable at "D"-4, and 89 percent found the odor objectionable at the "D"-6 level.

Horizontal exhaust at bumper height from a city bus was found to be diluted to a minimum reasonable level of 100:1 before being experienced by an observer. This dilution level was used in the odor test of both HD engines and Diesel LDV's. As it is uncertain that this is the reasonable minimum dilution level from a Diesel powered passenger car, a higher dilution level (550:1) was also employed. References 1 and 4 describe the odor facility and References 2, 3, and 4 describe the development of procedures and operating conditions for research purposes.

b. Test Conditions

Both steady-state and transient vehicle operation were simulated for odor evaluation.

(1) Heavy-Duty Engines

Odor measurements were made from the Diesel engines while operated on a stationary dynamometer (see Figure 1a and 1b). The same large inertia wheels used in the Federal smoke test were employed to simulate vehicle acceleration and deceleration.

Simulation of the seven steady-state conditions that comprised each morning's odor test runs was as easily accomplished on the stationary dynamometer as with the chassis dynamometer vehicles. The seven conditions, a curb idle in neutral, 2, 50, and 100 percent of maximum power at each of two speeds (intermediate and rated), are replicated three times in random order for a total of 21 runs. Thus, most of the same conditions used for gaseous emissions by the 13-mode test are used.

The afternoon runs included three conditions, each replicated four times in random order. The acceleration after a prolonged curb idle is meant to represent the repetitive idle-acceleration of city buses and the acceleration in a low gear of large trucks. It was simulated by using the large inertia wheel without dynamometer preload and merely advancing the engine fuel control to the "full-rack" or maximum power demand position. The panel then rated the odor perceived during this rapid acceleration. Pretest investigation revealed a specific time during the acceleration when maximum odor levels were produced.

Table 5 lists the times and engine condition when the odor was evaluated. The acceleration condition follows a brief cruise and is intended to simulate the upshift of a vehicle into a higher gear. It was performed at maximum "rack" or power position. The deceleration condition investigated the odor levels produced during the "closed-rack", no fuel demand position of the pump and simulates the deceleration of the vehicle from cruise. In both the acceleration and deceleration conditions, inertia and a pretest dynamometer load were used to simulate the vehicle operation.

A cold start condition was run at the start of each day's testing and brought the total number of conditions up to eleven. In all transient runs, the odor measurement was at a predetermined point that produces the most noticeable odor level. The transients along with the steady-state "odor map" provide a comprehensive evaluation of the engine's exhaust odor. The use of the trained panel was limited to the Mack ETAY(B)673A and the Caterpillar 3208/EGR engines evaluated.

(2) Light-Duty Vehicles

The odor measurement procedures applied to the Diesel-powered cars was in keeping with that used in 1974-1976(14-17,19) and was based on the extensive previous work with Diesel exhaust odor measurement from larger size vehicles. The basic philosophy was to characterize odor over a range of loads and speeds that could be encountered and over a wide enough range to cover steep uphill plus moderate trailer towing as well as the moderate load and no load conditions.

Table 6 lists pertinent operating data for each of the test conditions. The steady-state runs were made at three power levels, normally zero, mid and high power at a high and at an intermediate speed. The seventh condition was a low idle of a well warmed-up engine. Midload was defined as a fuel rate midway between the fuel rates at full and no load (transmission in neutral). These seven conditions were performed in random order so as to replicate each condition three times for a total of 21 runs. Cold start odor ratings were taken with both cars at the start of each testing day.

In keeping with the procedure used in Part VII(16), high speed was defined as the engine rpm corresponding to 90.1 km/hr (56 mph) level road load. The intermediate engine speed was then defined as 60 percent of this speed. In the afternoon, an acceleration after upshift, a deceleration after a cruise, and an acceleration after idle were run in replicate. Road load plus an appropriate-sized inertia wheel was employed to simulate the acceleration and deceleration performance of the vehicle.

TABLE 5. ODOR TEST CONDITIONS - HD ENGINES

		Mack ETAY(B)673A	Caterpillar 3208/EGR
		Steady-State Operation	
Engine Speed, rpm,	High	1900	2800
	Inter	1450	1680
	Idle	625	600
Kw @ High Speed,	100%	244	150.3
	50%	122	75.2
	2%	4.9	2.8
Kw @ Inter Speed,	100%	226.7	116.9
	50%	113.4	58.5
	2%	4.5	2.1
		Transient Conditions	
Idle-Accel, rpm	start	625	600
	end	1900	2800
Odor Test rpm		1200	1600
Accel time, sec		4	4.1
Accel range, rpm	start	1400	1600
	end	1900	2800
Odor Test rpm		1800	2600
Accel time, sec		9.5	10.2
Decel range, rpm	start	1900	2800
	end	625	600
Odor test rpm		1400	2000
Decel time, sec		7	5.2

TABLE 6. ODOR TEST CONDITIONS

Condition	Parameter	Cutlass Diesel	Rabbit Diesel
Intermediate Speed, No Load	Engine rpm-Vehicle km/hr	1400-0	2020-0
	Fuel kg/hr-Air kg/min	2.00-0.60	0.54-1.48
	Drive Gear	N	N
Intermediate Speed, Mid Load	Engine rpm-Vehicle km/hr	1400-57.9	2020-53.1
	Fuel kg/hr-Air kg/min	4.31-0.61	2.54-1.50
	Drive Gear	D-3	4
Intermediate Speed, High Load	Engine rpm-Vehicle km/hr	1400-41.8	2020-53.1
	Fuel kg/hr-Air kg/min	6.62-0.62	4.54-1.42
	Drive Gear	D-3	4
High Speed, No Load	Engine rpm-Vehicle km/hr	1920-0	3360-0
	Fuel kg/hr-Air kg/min	3.27-0.90	1.32-2.45
	Drive Gear	N	N
High Speed, Mid Load	Engine rpm-Vehicle km/hr	1920-86.9	3360-90.1
	Fuel kg/hr-Air kg/min	8.89-0.90	5.08-2.46
	Drive Gear	D-3	4
High Speed, High Load	Engine rpm-Vehicle km/hr	1920-82.1	3360-90.1
	Fuel kg/hr-Air kg/min	14.51-0.90	8.85-2.38
	Drive Gear	D-3	4
Idle	Engine rpm-Vehicle km/hr	630-0	900-0
	Fuel kg/hr-Air kg/min	1.00-0.26	0.27-0.62
	Drive Gear	N	N
Idle-Acceleration	Vehicle km/hr, Start-End	0-40.2	0-32.2
	Odor Test rpm-km/hr	1900-32.2	2300-24.1
	Gear Driven In	D-1	1
Acceleration	Vehicle km/hr, Start-End	40.2-80.5	48.3-80.5
	Odor Test rpm-km/hr	1600-72.4	2680-72.3
	Gear Driven In	D-3	4
Deceleration	Vehicle km/hr, Start-End	80.5-48.3	80.5-48.3
	Odor Test rpm-km/hr	1310-56.3	2150-56.3
	Gear Driven In	D-3	4

c. Diesel Odor Analytical System

As one result of approximately five years of research, sponsored under the CAPE-7 project of CRC APRAC, A. D. Little developed a prototype liquid chromatograph for use in predicting Diesel exhaust odor. Called DOAS for Diesel Odor Analytical System, the system provides two results--one being an indication of the oxygenate fraction called LCO for liquid chromatograph oxygenates and the other called LCA for liquid chromatograph aromatics. These were found by earlier research by A. D. Little to represent the major odorants in Diesel exhaust.(56-59) The A. D. Little studies had shown a correlation of the TIA (total intensity of aroma) to sensory measurements by the A. D. Little odor panel.(60) TIA is equal to 1 + $\log_{10}$ LCO.

Both LCO and LCA are expressed in micrograms per litre of exhaust using either the test fuel or a reference component for calibration. The LCO is, by virtue of its use to express TIA, considered the most important indication of Diesel exhaust by this method. An entire series of reports have been published by A. D. Little describing their work with Diesel odor.(36-40) Reference 40 describes the DOAS and its use, while Appendix C in this same reference describes the sample collection procedure. For additional details of the application of this instrument, please refer to the Part VII final report.(16)

The sampling interface system, shown by the lower left photo in Figure 5, follows good laboratory practice as applied to Diesel hydrocarbon measurement. Most of the sampling system was housed in an oven held at 190°C (375°F). Each system, of which three separate ones are available, began with a multiopening stainless steel probe located in the exhaust stack. This is normal practice for HC measurement from HDD engines. The sample was then transferred to the oven via a 9.5 mm (3/8 inch) diameter stainless steel line 0.75 m (30 inches) long covered by tubular exterior electrical heating sleeves to maintain 190°C (375°F) sample gas temperature. Between the probe and sample transfer line, a high temperature bellows type stainless valve was placed for leak check purposes. Inside the oven, the sample passed through a fiberglass filter, then into a square head welded metal bellows (stainless) pump head mounted inside the oven.

Immediately as the flow exits the oven wall, the DOAS trap is mounted so that it is accessible for change but is not located where the sample could have intentionally cooled. Once the sample passes through the trap, the sample goes through a drierite column, a glass tube flowmeter, and then into a dry gas volume meter. The desiccant removes troublesome water which condenses in the flowmeter and gas meter. The flowmeter allows monitoring of gas flow, by visual observation, during the test while the gas meter measures the total flow of gas during the test run. The DOAS liquid chromatograph analysis instrument is shown in the lower right photo of Figure 5. The syringe injection is being made of the trap collected Diesel odorants.

From data given in Reference 15, a relationship between "TIA" and "D" was found to be

$$\text{"D"} = -2 + 3.2(\text{TIA})$$

For a TIA value of 1.875, the "D" value would be 4, which is quite objectionable by the opinion survey.(24) A. D. Little feels that the relationship is

$$TIA = 0.2 + .32"D"$$

For "D"-4, TIA is 1.48. Thus, for a quite objectionable level of "D"-4, the corresponding TIA value might be between about 1.5 to 1.9.

d. Gaseous emissions

Gaseous emissions were also taken during the steady-state speed-load odor maps. Measurements included HC by heated FID; CO_2, NO, and CO by NDIR; NO and NO_x by chemiluminescence (CL); oxygenates; and various NRHC. The seven conditions, in triplicate (21 runs), were repeated on two mornings normally separated by one day for analysis and preparation. The upper left photograph of Figure 6 shows the 13-mode Diesel emissions instrumentation also used during the odor testing.

These measurements were intended to define the steady-state performance and characterize emissions beyond that possible from the LDV transient procedures and the 1974 HD FTP 13-mode test. Also, the data would be useful in comparison with and correlation to the odor panel ratings and other measurements by the CAPE-7 DOAS instrument. Figure 6 (upper right view) shows the gaseous emissions instruments for CVS collected bags. The center left view of Figure 6 shows the entry to the CVS where the LDV hydrocarbon, DOAS and other related materials were sampled during transient operation. The center right photo shows the CVS, sample bags, and, in the background, the heated FID for continuous HC measurement. The lower left photo of Figure 6 shows the HC instrument in more detail.

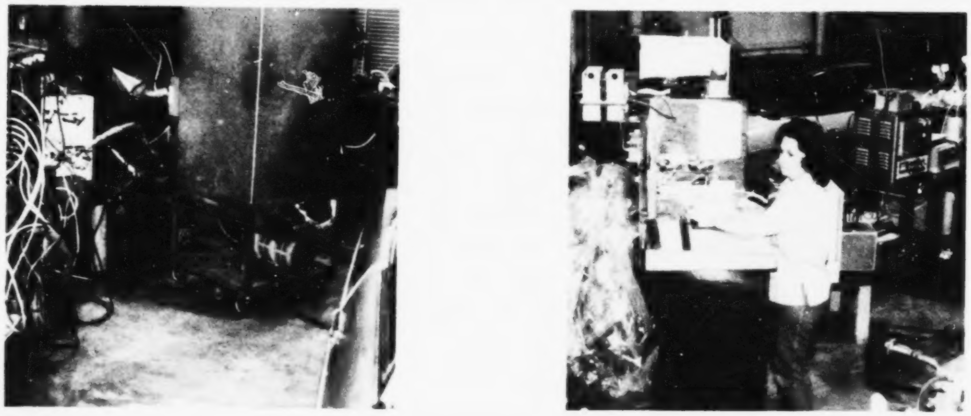
e. Partially Oxygenated Compounds - DNPH

The DNPH method, as described by the procedure in Appendix B of Part VII Final Report(16), was obtained from Dr. Ronald Bradow of EPA-RTP. Although wet collection traps are used, a GC is employed and there are many intermediate steps in the preparation of the sample once collected. Seven separate samples were obtained. Each sample contained the three replications and represented 12 to 15 minutes of sample absorption in the glass bubbler trap system with 4 to 5 minutes of trapping each run. The seven runs were made on the first day of the 2-day sequence for each engine or vehicle. Figure 6 (lower right photo) shows a partial view of the glass bubbler traps with the cold bath removed.

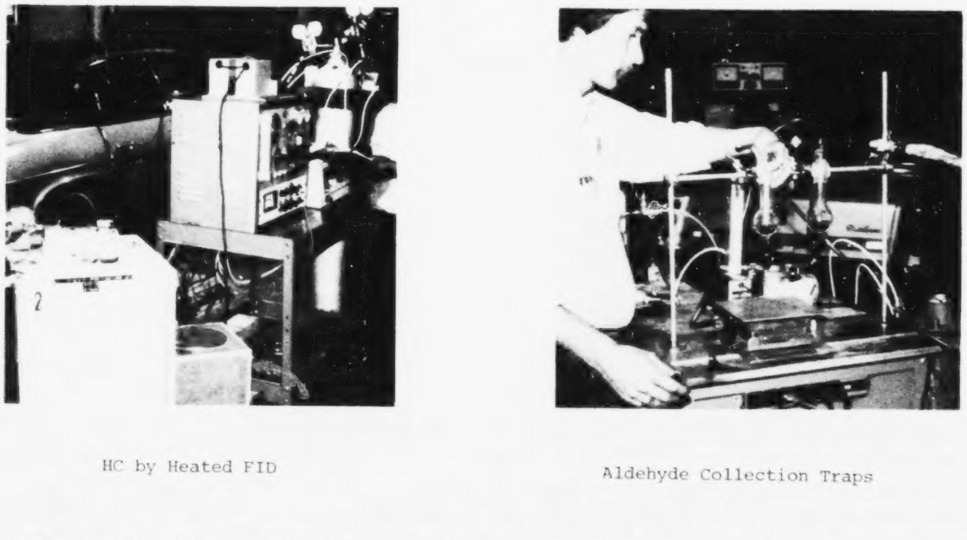
f. Characterization of Specific Hydrocarbons

The measurement of a variety of hydrocarbons was performed using a gas chromatograph procedure developed by EPA-RTP.(61) This procedure uses a single flame ionization detector with a multiple column arrangement and dual gas sampling valves. The timed sequence selection valves allow for the baseline separation of air, methane, ethane, ethylene, acetylene, propane, propylene, benzene, and toluene. Only methane is generally considered nonreactive in photochemical reactions. Ethane, propane, benzene, and acetylene are considered reactive even though only to a small degree. Propylene, ethylene, and toluene are known to react to form photochemical smog.

Gaseous Emissions HD and LD Vehicles



CVS - Continuous Trap/Analysis



HC by Heated FID

Aldehyde Collection Traps

Figure 6. Gaseous Emissions Measurement Instruments and Apparatus

Samples were obtained directly from the bag samples of FTP, SET, and FET transient LD cycles (as shown in Figure 6, right center and upper photos) and 7 modes used during all odor testing and analyzed. Individual values were determined for the bag or run. A detailed description of the individual columns, temperature, flow rates, etc., may be found in Reference 61.

6. Particulate

The mass rate of emission of particulate from both HD engines and LDV's was determined by collecting a known amount of particulate matter on a preweighed glass fiber filter. The 47 mm diameter Gelman Type A glass fiber media was the principal size and type of filter disc employed. Particulate mass rates were also obtained using both an 8 x 10 size fiberglass filter for polynuclear aromatic (PNA) compound analysis and by Fluoropore (Millipore Corporation) 47 mm plastic filter media with 0.5 micron mean pore flow size. The Fluoropore filters were used for sulfate collection.

The basic technique for sample collection was to dilute the exhaust with prefiltered air much the same as the constant volume sampler does with the exhaust in the LDV-FTP for gaseous emissions. The definition of particulate was in terms of the dilution and collection media and, importantly, the temperature at the point of filtration. In keeping with EPA definition of Diesel engine particulate from Reference 31, anything that was collected on Type A glass fiber filter at a temperature not to exceed 51.7°C (125°F) and not condensed water was considered Diesel particulate. The particulate thus included aerosols and unburned fuel-like matter. Most tests were made at lower average temperatures and depended on the exhaust volume, temperature, and dilution level.

The nominal 0.457 m (18-inch) diameter by 4.88 m (16-foot) long dilution tunnel used to dilute and cool the exhaust is shown in the Figure 7 schematic drawing. The pertinent dimensions, flows, velocities, and the relationship of the various components which make up a particulate collection system are indicated. A microbalance, with 1 microgram accuracy and housed in a special humidity-temperature controlled environment, was used to weigh the filters before and after the test. The weighing box is supplied with prefiltered, scrubbed air at a constant 22.2±0.06°C (72±1°F), 10.6±0.3 g/kg (74±2 gr/lb dry air) humidity at 0.3 m^3/hr (10 cfm).

a. HD Engine Particulate

The large volumes of hot exhaust from the Diesel engines used in trucks and buses preclude the practical dilution of all the exhaust in a laboratory size dilution tunnel. This was recognized at the outset of SwRI's initial efforts to characterize particulates for EPA under Contract No. 68-02-1230 for RTP. In order to use the fairly standard EPA design 0.457 m (18-inch) tunnel, an exhaust flow splitting system was devised whereby only a part of the exhaust is used in the tunnel and the remainder vented to the atmosphere. Obtaining a true split of the exhaust is a difficult job, and even more difficult is knowing how much of the exhaust is split and diluted by the tunnel. With much care and attention to detail, this can be done with reasonable accuracy and repeatability.

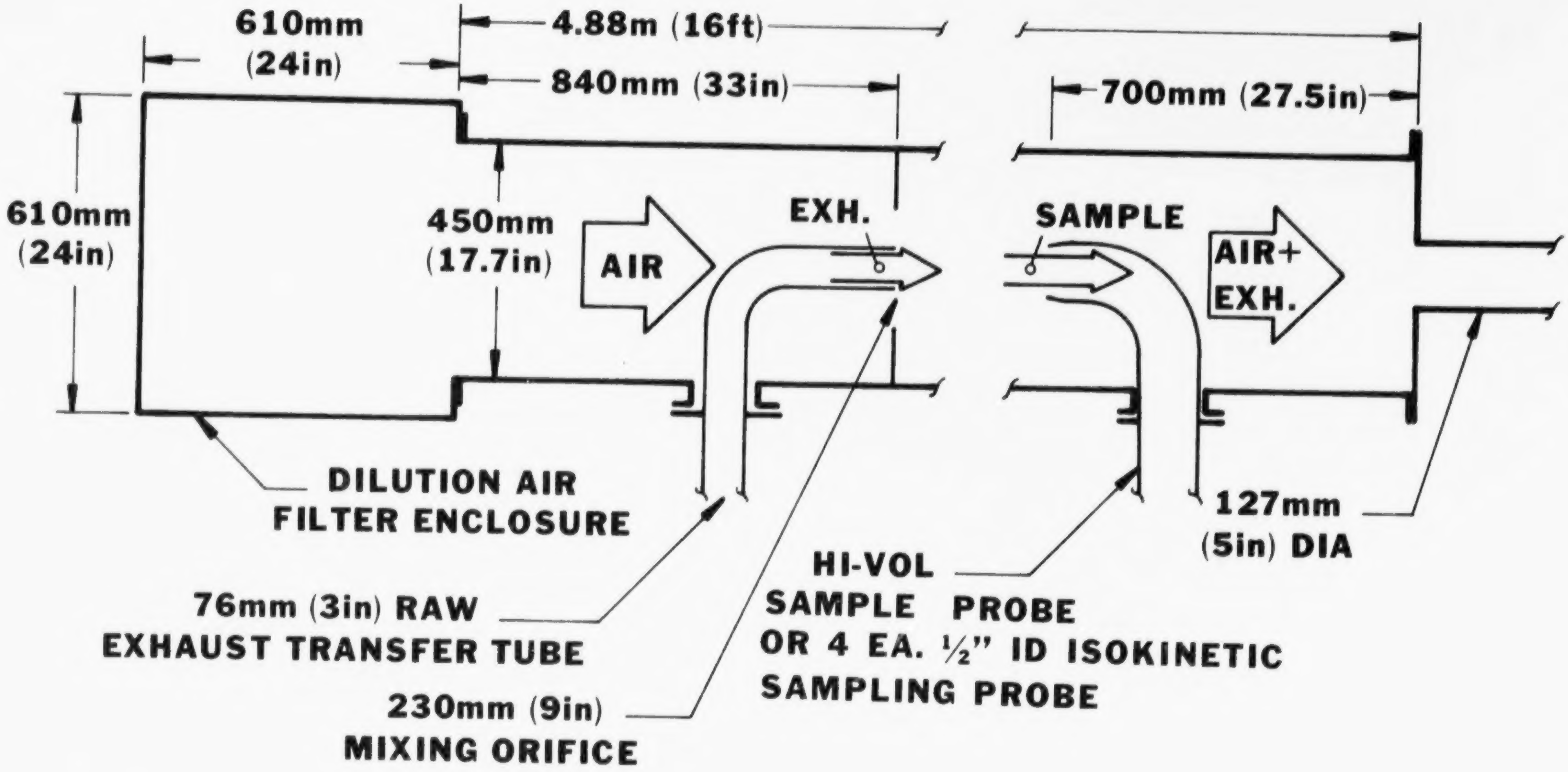

610mm
(24in)
4.88m (16ft)
840mm (33in)
700mm (27.5in)
610mm
(24in)
450mm
(17.7in)
AIR
EXH.
SAMPLE
AIR+
EXH.
DILUTION AIR
FILTER ENCLOSURE
76mm (3in) RAW
EXHAUST TRANSFER TUBE
230mm (9in)
MIXING ORIFICE
HI-VOL
SAMPLE PROBE
OR 4 EA. ½" ID ISOKINETIC
SAMPLING PROBE
127mm
(5in) DIA

Figure 7. Schematic Section of Dilution Tunnel for Diesel Particulate Sampling

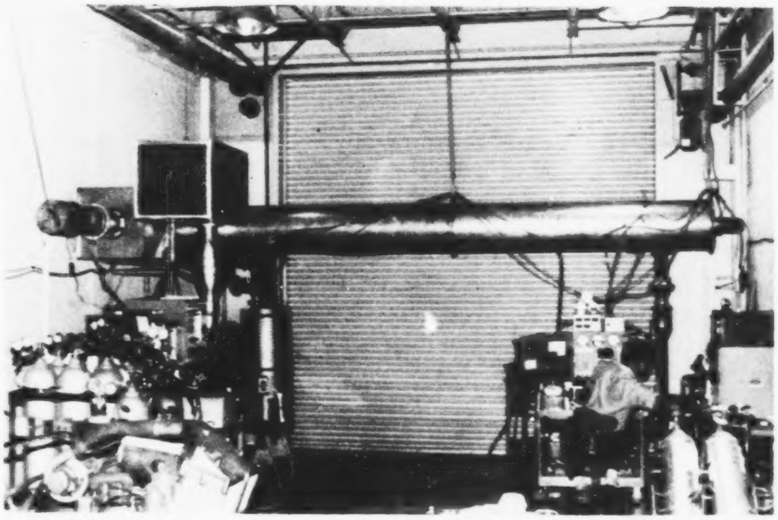
After review of several possible flow splitters, it was determined that the vehicle exhaust muffler was the most realistic point to obtain a split of the total exhaust that retained all of the properties and characteristics of the bulk exhaust. Adjacent to the usual exhaust outlet from the conventionally used stock muffler, a second but somewhat smaller outlet was added. As with the stock muffler outlet, an open-ended tube with the same length and wall perforations, diameter, and pattern was fabricated and inserted inside of the muffler in a similar fashion to the stock outlet tube. By trying several size tubes, the exhaust flow could be matched to the filter temperature for given operating conditions of the test sequence. The use of a "sampling tube" within the muffler of similar design to that for the stock outlet was thought to give the exhaust a similar opportunity to flow out either tube and thus preserve the integrity of the sample.

The use of a large gate valve on the vented exhaust flow allowed the use of slight exhaust system backpressure so that some measure of control was available. The exhaust backpressure was generally set at the engine manufacturer's maximum allowable at rated speed and load, as in the 13-mode FTP. At other speeds and loads, the backpressure was allowed to decrease to a value consistent with lower engine speeds and exhaust flows without adjustment of the preset restriction.

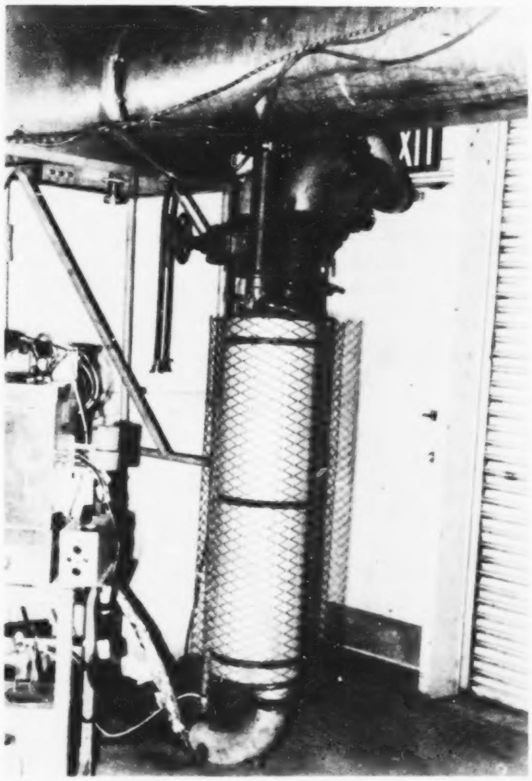
The exhaust sampling and dilution system was, for the HD engines, identical to that described in References 16 and 31. It is shown pictorially in Figure 8 for use with HD engines. The center right photo is of the splitter and the tunnel used with all HD engines except the Caterpillar 3406 and shows the particulate and charcoal filtered intake system. A close-up of the exhaust system and muffler-splitter arrangement is shown in the lower left and right view of Figure 8. Notice the large gate valve used for backpressure and dilution level control. The tunnel photographs of Figure 8 show the large truck muffler located vertically under the tunnel. Part of the exhaust then enters directly into the tunnel and filter samples are taken downstream.

The amount of exhaust that was eventually diluted and from which the particulate samples were obtained was based on the difference between the calibrated positive displacement pump (PDP) flow and the amount of dilution air measured by a calibrated laminar flow meter. The difference in two large measurements, each subject to error, can lead to larger than usually desired errors in the difference. Thus, the most crucial part of the system is the care and precision in obtaining both PDP and makeup or dilution air flows. To assure a measure of quality control, the dilution tunnel was treated as a CVS and subjected to the same number and stringency of checks to include propane recoveries on a weekly basis and daily laminar flow meter - PDP correlation tests.

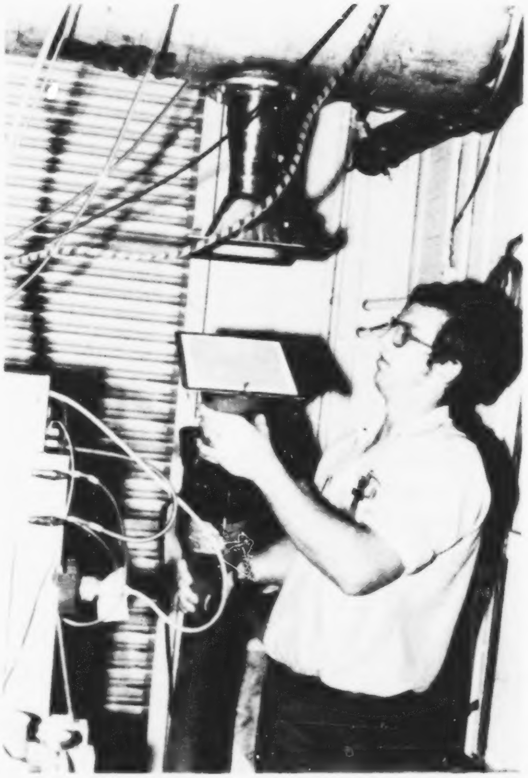
Particulate and sulfate samples were obtained on all HDD engines at each of the 11 different modes of the 13-mode FTP. Idle was only sampled once. Those engines for which motoring was performed, samples were also obtained under closed throttle operation. For BaP and organic solubles, a 7-mode test consisting of idle and 2, 50, and 100 percent power at rated and intermediate speeds was run.



Dilution Tunnel



Exhaust Splitter



Sample Filter

Figure 8. Particulate Measuring Equipment (HD Engines)

b. LDV Particulate

The dilution tunnel was quite capable of handling the entire exhaust from both Diesel and gasoline powered LDV's without exceeding the 51.2°C (125°F) sample temperature. The dilution tunnel nominal flow of 14.15 m^3/min (500 cfm) was not excessive in overdiluting necessarily but is greater than would normally be used in a gaseous emissions test by conventional CVS technique. The particulate tests were performed separately from the gaseous emission tests and used the same type tunnel as in the HD engine testing.

In order to achieve a sufficient sample and because there is no convenient means to switch particulate samples at the 505-second point in the city driving schedule, all cold start FTP's were for the entire 23 minutes on a given filter. The 10-minute soak period was then observed and then an additional full 23-minute city driving cycle repeated from a hot start. The other two transient driving cycles were from a hot start with the sample for the SET and for the FET collected on separate filters.

The four sample systems permitted the collection of two each particulate samples on 47 mm glass and two each sulfate samples on 47 mm Fluoropore media. The testing sequence of cold-hot FTP, SET, and FET was repeated on several successive days. This test sequence was then performed with the high-volume sampler to obtain larger amounts of particulate for PNA analysis using the 8 x 10 size glass filters.

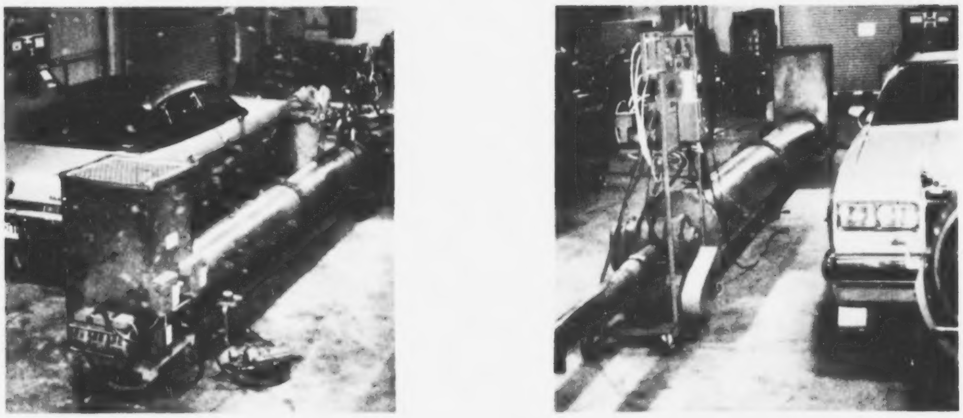
The various photographs in Figure 9 show the dilution tunnel as used with all four cars. The dilution tunnel was located alongside the car, as shown in the upper left and right views. The positive displacement blower and the four sampling filter systems are shown in the upper right views. The two center views illustrate the appearance of the 47 mm and 8 x 10 size fiberglass filter media at the conclusion of a test.

7. Sulfate Analysis

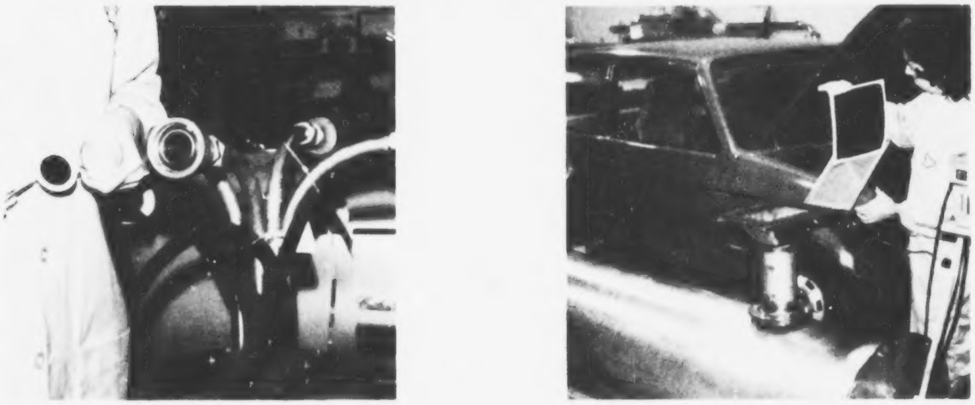
The methods used to collect the samples of sulfate were discussed in the previous subsection. For analysis of sulfate, the BCA method was used with both gasoline and Diesel engines. The BCA method for sulfate had been widely used with gasoline-powered LDV's under EPA Contract 68-03-2118 and during Part VII Diesel studies. A description of the BCA test procedure may be found in Appendix B of this report. The lower left photo of Figure 9 shows the BCA analysis instrumentation.

One requirement of the project was to try and analyze sulfate from a leaded gasoline fueled HD truck engine. This experiment gave very confusing results and not due to the well-known positive interference of lead combustion products. The problem was extremely low readings during the initial analysis. Some nine weeks later, the solutions were reanalyzed and the values had increased substantially. The reasons remain unknown.

In the case of Diesel engines, it is not certain what form the sulfate is in when it exits the engine or vehicle. There is no evidence to prove that it is in the form of sulfuric acid mist, as is the case with oxidation equipped, gasoline fueled cars. In fact, the lack of an observable



Dilution Tunnel Particulate Measurement-Cars



47 mm and 8 X 10 size Filter Collected Particulate

BCA-Sulfate Analysis

LDV Sound Level Meter

Figure 9. LDV Particulate Sulfate and Noise Measurement Equipment

storage-purge characteristic of Diesels suggests that such may not be the case. Until this issue is resolved, it is proper to refer to what is measured as sulfate or, more correctly, sulfate by BCA.

8. Polynuclear Aromatic Matter (PNA)

PNA compounds as a class and as individual contaminants were of interest in this project. Although there are several laboratory procedures available for their analysis, the major difficulty was analysis of PNA materials in Diesel exhaust and, of equal importance, the collection of a sample in a form suitable for such laboratory analysis. This was amply demonstrated by the difficulties encountered by Gulf Research and Development under the CRC APRAC CAPE-24-72 project. It was further illustrated in the degree of difficulty and inadequacy of available methods by the Southwest Foundation for Research and Education (SwFRE) during the Part VII Diesel work(16) and that for RTP under Contract 68-02-0123. Even the measurement of benzo(a)pyrene (BaP) was highly questionable.

At the outset of this project, it was decided to continue using the SwFRE method for BaP analysis until a better method could be obtained. Shortly after completion of the Mack ETAY(B)673A HDD engine, it was agreed to forward all subsequent filters to Dr. Robert Jungers, Chief of the Source, Fuels, and Molecular Chemistry Section of the Environmental Monitoring and Support Laboratory, Environmental Protection Agency, Research Triangle Park, North Carolina, for the soxhlet extractions and BaP analyses. This was done on all subsequent HD engines. However, the Mack as well as the two Diesel and the two gasoline cars were analyzed for BaP by SwFRE.

The Sawicki analysis procedure(62), for determination of BaP, involved a thin layer chromatographic separation followed by fluorescence measurement. This was the basic analytical method used by SwFRE. BaP is an elementary PNA and is generally found in Diesel exhaust. It is considered to be a good indicator of the relative PNA content in that if it is high, other PNA emissions are also probably high. There was, at the time of its use on this project, still some unresolved questions regarding the sample collection and especially the preparation of the sample for analysis. For additional description of the procedure, please refer to Appendix B.

The method used by EPA-RTP for BaP(63) is also described in Appendix B. Extractions of 8 x 10 filter halves produced samples for BaP analysis. The extracts were concentrated and spotted on TLC plates, and the plates were scanned by a Perkin-Elmer MPF-3 fluorescence spectrophotometer. Excitation was at a wavelength of 388 nm, and emission was read at 430 nm.

The soluble extract of the filters was obtained using two different solvents. In the case of the filters analyzed by SwFRE (all cars plus Mack engine), benzene was used. Thus, the percent organic soluble of the total filter weight is based on its use. Benzene was used as the solvent for the Caterpillar 3406 DI with EGR and timing experiments. Cyclohexane was used for the Caterpillar IDI configuration, both Daimler-Benz engines and the Mack APS-standard pump comparisons.

The measurement of Diesel BaP by the present method at EPA is considered an interim procedure. As soon as the high pressure liquid chromatograph (HPLC) method being developed by EPA is qualified, a powerful new tool should be available to investigate a series of PNA materials and not just BaP.

Among the unresolved issues is the role of carbon in the exhaust and on the filter in the collection of PNA's by the dilution tunnel method. The general lack of PNA's from oxidation catalyst equipped cars, as found in this effort, may be attributed to the catalyst or to the fact that carbon content in the exhaust was negligible. In the case of the non-catalyst HD gasoline engine, two modes produced exceptionally high BaP levels and others were negligible. The use of dilution tunnel sampling methods may be a desired approach to laboratory testing but may produce inconsistent or low values due to collection efficiency of the filter. Much more needs to be done to qualify and validate the sample collection, extraction, and, of course, the HPLC procedure.

9. Elemental Analyses

Determination of carbon, hydrogen, and nitrogen weight percentages in Diesel particulate were also performed by Galbraith Laboratories. Carbon and hydrogen were measured using ASTM method D-3178 and nitrogen was measured using ASTM D-3179. The results were corrected for blank filter content, which was reported to be very low.

Metals and other elements such as silica and sulfur were analyzed by X-ray fluorescence. The improved precision, reduced detection limits, and the even greater number of elements that could be analyzed by the X-ray instrument at EPA-RTP prompted a change from the U.S. Army Fuels and Lubricants Laboratory at Southwest Research Institute to the RTP laboratories. Thus, the four cars' Fluoropore filters were analyzed by the Army Laboratory while all the HD engines were performed by EPA-RTP. The analyses at EPA was arranged for through the cooperation of Dr. Ronald L. Bradow.

10. Vehicle Noise - LDV's Only

This series of tests was intended to determine the maximum interior and exterior sound levels, in dBA scale, during idle and various driving modes. SAE J-986a, Sound Level for Passenger Cars and Light Trucks, describes a test procedure that formed the basis for measurement and vehicle operation. A General Radio Type 1933 Precision Sound Level Analyzer, General Radio Type 1562-A Sound Level Calibrator, and General Radio Wind Screen, meeting the requirements of International Electrotechnical Commission Publication 179, were used.

a. Acceleration Drive-By

Exterior drive-by measurements were made at 15.24 m (50 feet) using the test procedure outlined in SAE J-986a. Under this test, each vehicle approached a line 7.6 m (25 feet) before a line through the microphone normal to the vehicle path and accelerated using the lowest transmission gear or range such that the front of the vehicle reached or passed a line 7.6 m (25 feet) beyond the microphone line when maximum rated engine speed was reached. The equipment used was a precision sound level meter, a sound level calibrator, and a calibrated wind screen. The test site was (as outlined in J-986a) a flat open space, free of large reflecting surfaces (i.e., signs, hills, buildings) within 30.5 m (100 feet) of the test track.

Measurements were made (as outlined in J-986a) 1.22 m (4 feet) above ground level and at 15.24 m (50 feet) from the centerline of the vehicle. This distance was considered adequate if the maximum noise level as measured on the "A-weighted" scale with a "fast" meter response was 10 dB above the ambient noise level. If this criterion could not be met, the measurements were made at 7.6 m (25 feet) by subtracting 6 dB from the measured values to extrapolate to an equivalent reading at 15.24 m (50 feet). If the level at 7.6 m (25 feet) was not 10 dB above ambient levels on a reasonably quiet day, this point was noted as well as the measured level and ambient level. The sound level for each side of the vehicle was the average of the two highest readings which were within 2 dB of each other. These were made with all windows fully closed and the vehicle accessories such as heater, air conditioner, or defroster (radio excluded) in operation at their highest apparent noise level.

Interior sound level determinations were the same as exterior except that the microphone was located 0.152 m (6 inches) to the right side of the driver's right ear. All other test procedures were as presented in J-986a. The lower right photo of Figure 9 shows the hand-held meter adjacent to the driver's right ear during the interior measurements.

b. Constant Speed Drive-By

The exterior noise level with the vehicle passing by the microphone at a distance of 15.24 m (50 feet) was measured. The vehicle was in high gear and driven smoothly at 48.3 km/hr (30 mph) ±5 percent. As in the acceleration test, the measurement was made at 7.6 m (25 feet) if "fast" meter response was not 10 dB above ambient noise level on the "A-weighted" scale. Six dB was subtracted from the measured values to extrapolate to an equivalent reading at 50 feet. Interior sound level determinations were made in the same manner as during the acceleration test. The sound level reported for this test was obtained in the manner outlined in the acceleration test already described.

c. Idle

This test included sound level measurements at 3.05 m (10 feet) distances from the front, rear, left (street side) and right (curb side) of the vehicle. The vehicle was parked and engine allowed to run at manufacturer's recommended low idle speed with transmission in neutral for at least one minute. Accessory items such as air conditioner or heater and defroster (radio excluded) operated at their highest apparent noise level. The sound level meter was positioned 3.05 m from each bumper midway between the sides of the car and 3.05 m from each side midway between the front and rear bumpers at 1.22 m (4 feet) height above the ground. The vehicle was then turned around and headed in the opposite direction and measurements repeated. Interior measurements were also obtained at the same single point used in drive-by tests. The test course was identical to that employed in the earlier work and reported in References 12, 14, 16, 21, and 22.

F. Weighting Factors - HD Engines

Appendix A is the experimental 23-mode EPA HD engine test procedure. Weighting factors are listed in paragraph 85.102, dynamometer operation cycle of this procedure. These factors (relisted in Table 7) as well as the 13-mode FTP weighting factors (listed in Table 8) formed the basis for most of the calculations to determine emission rates and cycle weighted fuel consumption of the HD engines. The need for various short cycle weighting factors was to accommodate the many engines and the test plan for the varied nonregulated emissions.

The 21-mode factors are shown on Table 7 to include the same modes as the 23-mode EPA test but without the closed throttles. The deletion of the closed throttle weighting factors reduced the total to 82 percent of the time. Thus, the remaining 21 modes weighting factors were increased by the ratio of 100/82.

The 13-mode test using factors derived from the 23-mode test involved extension of the clossed throttle factors and adding the three separate idle factors into a single factor. The remaining mode weights were distributed as follows:

- 2% power represents 0 to 12.5% power; this range includes the 2% and 8% power points.

- 25% power represents 12.5% to 37.5% power; this range includes the 18% and 25% power points.

- 50% power represents 37.5% to 62.5% power; this range includes the 50% power point.

- 75% power represents 62.5% to 87.5% power; this range includes the 75% and 82% power points.

- 100% power represents 87.5% to 100% power; this range includes the 92% and 100% power points.

The 11-mode test is merely the 13-mode factors less the two closed throttles. The remaining modes were increased by 100/82 as with the 21-mode test factors.

The 9-mode test is a short cycle that still includes the two closed throttles and a single idle as in the 13-mode test. However, the remaining 2, 50, and 100 percent power points have increased weight due to the following redistribution:

- 2% power represents 0 to 25% power; this range includes the 2%, 8%, 18%, and half the 25% power points.

- 50% power represents 25% to 75% power; this range includes half the 25%, the 50%, and half the 75% power points.

- 100% power represents 75% to 100% power; this range includes half the 75%, the 82%, 92%, and 100% power points.

TABLE 7. EPA 23-MODE WEIGHTING FACTORS AND SHORT CYCLE WEIGHTING FACTORS DERIVED THEREFROM

23-Mode EPA				21-Mode		13-Mode		11-Mode		9-Mode		7-Mode	
Mode No.	Engine rpm	Power %	Weight Factor,%	Mode No.	Weight Factor,%	Mode No.	Weight Factor,%	Mode No.	Weight Factor,%	Mode No.	Weight Factor,%	Mode No.	Weight Factor,
1	Idle	0	7.0	1	8.5								
2	Inter	2	6.0	2	7.3	1	12.0	1	14.6	1	18.5	1	22.5
3	Inter	8	6.0	3	7.3								
4	Inter	18	5.0	4	6.1								
5	Inter	25	3.0	5	3.6	2	8.0	2	9.8				
6	Inter	50	6.0	6	7.3	3	6.0	3	7.3	2	7.5	2	9.2
7	Inter	75	0	7	0	4	4.0	4	4.9				
8	Inter	82	4.0	8	4.9								
9	Inter	92	0	9	0								
10	Inter	100	0	10	0	5	0	5	0	3	4	3	4.9
11	Idle	0	7.0	11	8.5	6	22.0	6	26.9	4	22.0	4	26.9
12	Inter	CT	12.0			7	12.0			5	12.0		
13	High	100	2.5	12	3.2	8	8.0	7	9.7	6	14.5	5	17.6
14	High	92	5.5	13	6.7								
15	High	82	3.5	14	4.3								
16	High	75	6.0	15	7.3	9	9.5	8	11.6				
17	High	50	6.0	16	7.3	10	6.0	9	7.3	7	9.0	6	11.0
18	High	25	0	17	0	11	6.5	10	7.9				
19	High	18	6.5	18	7.9								
20	High	8	0	19	0								
21	High	2	0	20	0	12	0			8	6.5	7	7.9
22	Idle	0	8.0	21	9.8			11	0				
23	High	CT	6.0			13	6.0			9	6		
	Total		100.0		100.0		100.0		100.0		100.0		100.0

TABLE 8. 13-MODE FTP WEIGHTING FACTORS AND SHORT CYCLE WEIGHTING FACTORS DERIVED THEREFROM

13-Mode FTP				7-Mode	
Mode No.	Engine rpm	Power %	Weight Factor, %	Mode No.	Weight Factor, %
1	Idle	---	6.7		
2	Inter	2	8.0	1	12
3	Inter	25	8.0		
4	Inter	50	8.0	2	16
5	Inter	75	8.0		
6	Inter	100	8.0	3	12
7	Idle	---	6.7	4	20
8	High	100	8.0	5	12
9	High	75	8.0		
10	High	50	8.0	6	16
11	High	25	8.0		
12	High	2	8.0	7	12
13	Idle	---	6.7		
			100.0		100

The 7-mode test is a very short cycle that is the same as the 9-mode test less the two closed throttles. The remaining modes were increased by 100/82 as with the 21- and 11-mode tests. The entire basis for all groupings and redistributions is one of time or percent of operating time given to a specific steady-state condition. Each condition is taken to represent all power output halfway to the adjoining power point or points. The basically linear nature of Diesel emissions with power output makes such an approach feasible. Thus, as the number of modes decreases, each point represents more time in mode and the mode represents a wider range of power.

Table 8 uses the same basis to derive the 7-mode weighting factors from the HD 13-mode FTP. Specifically, one idle is run and the weighting factor is 20 percent. The remaining factors are based on the following redistribution:

- 2% power represents 0 to 25% power; this range includes the 2% and half the 25% power points.
- 50% power represents 25% to 75% power; this range includes half the 25% and 75% and the 50% power points.
- 100% power represents 75% to 100% power; this range includes half the 75% and the 100% power points.

The short cycles and the weighting factors derived for their use in gaining cycle weighted composite values were used with selected experimental unregulated emissions data. For example, the difficult-to-analyze BaP was restricted to a 7-mode cycle instead of a 13- or 23-mode test.

IV. RESULTS OF HEAVY-DUTY ENGINE CHARACTERIZATION

This section summarizes the characterization emission data for the two HDD and one HDG engines evaluated. The two were the Mack ETAY(B)673A and the Caterpillar 3208 EGR. The gasoline engine, also described in Table 1, was a Chevrolet 366 and was run for comparison with the Caterpillar 3208 EGR, a midrange Diesel engine. The Caterpillar 3208 and Chevrolet 366 engines are used in many identical truck applications, and therefore a direct comparison is possible. More complete data relating to the characterization of these three engines may be found in Appendix C.

A. Gaseous Emissions

Table 9 lists the results of replicate emission tests using the experimental, multimode test designated the 23-Mode EPA test. Listed are the HC, CO, and NO_x rates as well as cycle weighted BSFC. This cycle and its weighting factors were described in Section III. The 23 modes include the test points of the 13-Mode Federal Test Procedure (FTP) for HDD, and therefore these values are also listed on Table 9 as computed values. Note that the Mack engine 23-mode results are really for a 21-mode test since dynamometer limitations would not allow operation under closed throttle (CT) motoring conditions. The weighting factors for the remaining 21 modes were increased proportionally and were discussed in Section III.

Table 10 lists the HDD emission limits for comparison purposes with the Table 9 data. Note the 1977 California limits list an alternate standard with HC and NO_2 limits specified separately. The manufacturer may certify either way. The mixed metric, g/bhp-hr, units of expression are listed in parentheses and are those currently listed in Federal and California regulations. For purposes of discussion, the results will be described by engine make and model.

1. Mack ETAY(B)673A

A modified version of the 23-mode test, which deleted the two motoring modes, was performed on the Mack ETAY(B)673A engine. In conversations with the Project Officer, it was agreed at the meeting at SwRI on November 10, 1976, to attempt the motoring modes on this particular engine if capability existed for doing so. The dynamometer facility on which this engine was being tested had a 500 hp Midwest absorption unit, inertia capability, and up to 50 hp belt driven motoring for special preselected speeds. Shortly after the meeting, it was learned from Mack Trucks that the motoring power at 1900 rpm was 65 hp and at 1450 rpm approximately 45 hp. The 50 hp motor available would not be able to run the 1900 rpm and only marginally able to run the 45 hp conditions. It was confirmed by Mack that the fuel injection pump and injectors feature positive shutoff of fuel, making measurements during closed throttle motoring of negligible consequence, according to Mack.

TABLE 9. EPA 23-MODE AND 13-MODE FTP GASEOUS EMISSIONS RATES

Engine	Type Test	Run No.	Brake Specific Emissions g/kw-hr (g-hp-hr)				Cycle BSFC kg/kw-hr (lbs/bhp-hr)
			CO	HC	NO_x	$HC+NO_x$	
Mack	21-Mode	1	2.157	0.674	7.965	8.639	0.246
ETAY(B)	EPA	2	2.143	0.635	8.047	8.683	0.247
673A	Average		2.150	0.655	8.006	8.661	0.247
			(1.604)	(0.489)	(5.972)	(6.461)	(0.405)
	13-Mode	1	2.173	0.592	8.691	9.283	0.243
	FTP	2	2.084	0.683	9.038	9.721	0.242
	Average		2.129	0.638	8.865	9.502	0.243
			(1.588)	(0.476)	(6.613)	(7.088)	(0.399)
Cat.	23-Mode	1	7.798	1.857	5.186	7.043	0.288
3208	EPA	2	9.228	1.708	4.958	6.666	0.291
EGR	Average		8.513	1.783	5.072	6.855	0.290
			(6.351)	(1.330)	(3.784)	(5.113)	(0.476)
	13-Mode	1	7.763	1.594	5.027	6.622	0.285
	FTP	2	8.856	1.524	5.019	6.543	0.288
	Average		8.310	1.559	5.023	6.583	0.287
			(6.200)	(1.163)	(3.747)	(4.911)	(0.472)
Chev.	23-Mode	1	73.50	3.31	4.41	7.72	0.462
366	EPA	2	74.01	3.36	4.70	8.06	0.463
Calif.	Average		73.76	3.34	4.56	7.89	0.463
			(55.00)	(2.49)	(3.39)	(5.88)	(0.761)

Note: NO_x is NO as NO_2 by NDIR for 13-Mode FTP.

TABLE 10. HEAVY-DUTY DIESEL AND GASOLINE EMISSION LIMITS

	Units	CO	HC+NO$_2$	
1973 California and 1974 Federal	g/kw-hr (g/bhp-hr)	53.6 (40)	21.4 (16)	
1975 California	g/kw-hr (g/bhp-hr)	40.2 (30)	13.4 (10)	
1977 California	g/kw-hr (g/bhp-hr)	33.5 (25)	6.7 (5)	
			HC	NO$_2$
1977 California (alternate)	g/kw-hr (g/bhp-hr)	33.5 (25)	1.3 (1)	10.1 (7.5)

Note: NO measured by nondispersive infrared and expressed as NO$_2$.

The duplicate modified 23-mode tests resulted in computation of a "13-mode" and "21-mode" composite emission rate. The "13-mode" result is based on NO as NO$_2$ by NDIR, while the "21-mode" is based on NO$_x$ by Cl, as per procedure. For reference, the emissions at the 1000-hour or final test of this engine during its use as a certification durability test were:

	CO	HC	NO$_2$	HC+NO$_2$
g/kw-hr	2.06	0.50	8.45	8.95
g/bhp-hr	1.54	0.37	6.30	6.67

Composite BSFC,	
kg/kw-hr	0.241
lbs/bhp-hr	0.396

These values, according to the 13-mode FTP, may be compared with the 13-mode values on Table 9. CO and NO$_2$ were quite comparable, while HC was higher, 0.638 versus 0.50 g/kw-hr, at the final 1000-hour test. BSFC was essentially identical. For additional details and the 21 modal values, please refer to Tables C-1 and C-2. Tables C-3 and C-4 are the 13-mode results derived from the 21-mode test.

2. Caterpillar 3208 EGR

The specific engine used in this project was a 1000-hour durability engine originally used for certification purposes at Caterpillar. Some operation was reported performed with the engine at Caterpillar for in-house development prior to its shipment to SwRI. This engine model, intended for California, was the first midrange size production Diesel engine equipped with exhaust gas recirculation (EGR). The method used by Caterpillar was to install a diverter valve at the outlet of the left engine exhaust manifold. Exhaust would then be directed back to the inlet of the intake manifold on a predetermined schedule. This is shown by the upper photo of Figure 10.

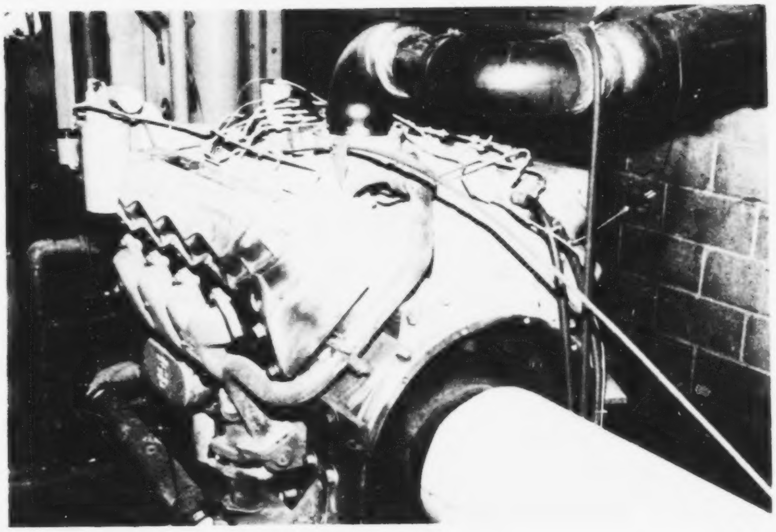
On completion of the initial replicate 23-mode gaseous emissions test of the Caterpillar 3208 engine, it was found that HC, CO, CO_2 and NO_2 were non-repeatable on certain modes and that certain modes were different from the emissions data given to SwRI by Mr. Don Dowdall of Caterpillar. This caused a great deal of concern by SwRI over the emissions data, especially since the engine power, fuel, BSFC and Federal Smoke Tests correlated well with Caterpillar's data. Smoke data will be described shortly.

After some investigation, it was found that the EGR valve would stick closed following operation at the full-power condition and that the general operation of the valve when hot was sluggish and unrepeatable. This valve and its positioning device is shown in the lower photograph in Figure 10 attached to the left exhaust manifold outlet. The valve has three positions, namely, a 40 percent EGR opening for all power levels of 55-57 percent and less, a 15 percent EGR position for the 75 percent power mode, and a closed 0-percent EGR position for power levels about 80±2 percent power. According to Mr. Jim Turner of Caterpillar, the erratic behavior of the valve and its sticking was attributed to a problem of the vendor of the item not finishing the valve per drawing, and this was rectified when the engine was released for production.

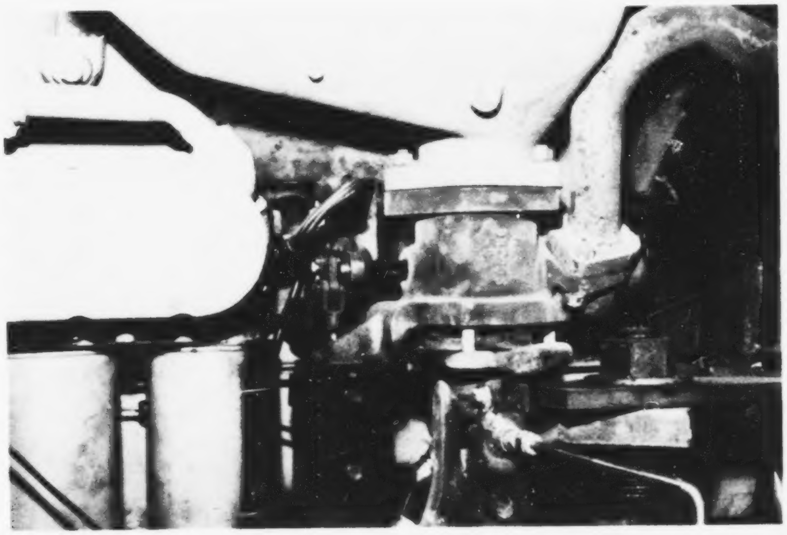
In subsequent telephone conversations with Mr. Turner and Mr. Bob Adams of Caterpillar, it was agreed that we could try to operate the valve manually by simulating the power demand. A system was devised so that the valve would be positioned with toggle switches to the oil solenoid valves that operate the valve. This approach was partially successful, except there still remained a variability in results. By this time, the test cell was rigged for smoke, as this was the quickest way to determine repeatability. After each maximum power or closed EGR position, the valve was manually rotated open to free it. A valve position arm was also added to visually check the valve rotation and location. However, the general binding of the valve gave doubt that the proper valve position was indeed regained each run. It was found that a slight change in valve position greatly affected smoke and gaseous emissions as well as BSFC. The most sensitive modes of the 13-mode test are the 50 and 75 percent power levels. The 82 percent point, required by the 23-mode test, is supersensitive since this is at the transition from partly open (15 percent EGR) to closed (0 percent EGR).

After extended attempts to operate the engine with the sticky valve, it was agreed to obtain a new, production type valve so that the engine could be run in its automatic mode. Mr. Bob Adams provided SwRI with such a valve. It was installed and found to operate freely when hot and not to stick in the closed position.

With the new valve installed, relatively high smoke was found at the 50 and 75 percent power points, on the order of 45 and 26 percent opacity at 2800 rpm and 12 and 13 percent opacity at 1680 rpm. Of major concern was the



Overall View of EGR System Operating
On Left Bank of Engine (Viewed from Flywheel)



Close-up of EGR Valve and
Automatic Positioning Device

Figure 10. Caterpillar 3208 with Automatic EGR

variability of smoke, i.e., smoke increasing with time as well as puffing, occasional spikes and smoke excursions.

In an attempt to obtain as repeatable data as possible, it was decided to use the ±2 percent tolerance in power afforded by the procedure and run modes 16 and 17 of the 23-mode test at slightly lower power yet within specifications.

Although certain of the modal smoke values seemed inordinately high, it was decided to start again and run the 23-mode gaseous emissions tests. These results, though some modes were erratic and nonrepeatable as other modes, were considered marginally satisfactory. It was not until the particulate test series was complete that the engine emissions, as indicated by particulate rate, had become intolerably erratic and the engine judged unsatisfactory for further operation.

A variety of experiments were made to attempt to diagnose the problem. The experiments included backpressure, inlet restriction, fuel, fuel delivery, and other engine parameters under automatic and manual EGR control. Each time, the symptoms pointed to the new EGR valve which still was observed to function properly and was found intact.

On May 31, 1977, Mr. Greg Garner of Caterpillar found the adjusting lock nut on the EGR valve actuating arm mechanism had loosened and changed in its setting. Once the adjustment was made to specification, the EGR valve then opened per the intended schedule and functioned properly.

On June 1, 1977, replicate gaseous emissions and modal smoke readings were obtained in Mr. Garner's presence to demonstrate engine performance. Table 9 lists these results. The third such series are considered to be representative of the engine. Copies of the computer sheets are contained in Appendix C as Tables C-5 through C-8. Tables C-5 and C-6 are the EPA 23-mode test results and Tables C-7 and C-8 are the 13-mode results derived from the EPA 23-mode test. These results are quite close to those reported by Caterpillar at the end of the 1000-hour test listed below.

	CO	HC	NO_2	$HC+NO_2$
g/kw-hr	9.85	1.60	5.16	6.75
g/bhp-hr	7.35	1.19	3.85	5.04

Composite BSFC, kg/kw-hr 0.289
lbs/bhp-hr 0.476

In subsequent discussions with Mr. Garner and Mr. Don Henderson of Caterpillar regarding these findings, it was learned that the replacement valve, installed earlier to replace the sticky valve that was originally on the 1000-hour engine, was removed from an engine under test at Caterpillar after 67 hours of operation. The replacement valve was, therefore, not shipped straight from production. It was agreed, from the test results of the valve as received and installed at SwRI and the results reported in this report with the re-adjusted valve, that the valve probably was not correctly set when received. If it had, then the smoke, CO and other emissions at full power would have agreed more closely than they did when first run at SwRI.

It is speculated that the valve lever adjustment nut had already loosened some prior to arrival at SwRI and that a slight amount of EGR was occurring at full power. As the engine continued to operate at SwRI, the adjustment continued to change so that more and more EGR was permitted, causing higher and higher smoke and particulate. The adjustment nut is not easily accessible once the valve is installed. Also, a special tool is needed to gage the interior opening or gap between the butterfly valve and its housing.

3. Chevrolet 366 Gasoline Engine

This gasoline engine was run for data that may be compared to the Caterpillar 3208 EGR engine. Prior to running the gaseous emission tests on this engine, Mr. Jim Feiten of Chevrolet was contacted to obtain tune-up specifications for the 1977 California 366 engine. The following lists the settings on the engine as received and as adjusted, with the knowledge and consent of Mr. Feiten.

Item	Specification	Observed	Adjusted to
Idle CO	0.50% CO	0.45	----
Idle rpm	700 rpm	780	700
Initial timing	8° BTDC @ 700 rpm	8° BTDC	----
Throttle kicker rpm	1400 rpm	1700	1400

While running the first preparatory test, it was found that the Chemiluminescence (CL) instrument could not function in the NO_x configuration at the 92 and 100 percent power modes. This was relayed to the Project Officer and a full discussion of this phenomenon given by both Mr. Charles Urban and Mr. Bob Srubar of SwRI. This has been observed before when using a heated CL instrument with raw exhaust from gasoline engines. For additional background on this problem, please refer to pages 17 and 18 of Reference 47. As agreed, the CL instrument was operated in the NO mode during the 92 and 100 percent power modes and the results reported as NO_x. All the other modes were run in the NO_x configuration.

Next, the engine was operated at selected steady states of the 9-mode FTP and the results compared to that furnished by Chevrolet per letter to Mr. Tom Baines from Mr. L. V. Faix of Chevrolet dated December 15, 1976. Fair agreement was found on emission concentrations. Fuel consumption and power output were lower at SwRI than at Chevrolet.

On rechecking the engine operation at 2300 rpm, HC was found intermittently high at the higher power modes of 82, 92 and 100 percent power. A split boot was found on the Number 7 spark plug wire at the spark plug and replaced. The audible misfire was eliminated. A Sun ignition analyzer was then connected to evaluate ignition variability for each cylinder. Considerable variability was found in the secondary pattern for each cylinder. This was eliminated on the installation of a new set of Chevrolet spark plug ignition wires for this HD engine. The wires on the engine, as received, were well worn.

On retesting the operation of the engine during the higher power modes, a substantial variation in CO concentration from trial to trial was noted during the 82, 92 and 100 percent power modes, but only at 2300 rpm. For example, CO in the 100 percent 2300 rpm mode ranged from 2.5 to 6.4 percent, depending on run. Visual inspection of the operation of the secondary venturi throttle plate revealed that the secondary venturi plate was apparently opening slightly and not to the same extent each time. The position could be changed drastically by a small change in the opening of the throttle plate in the primary venturis. Only by monitoring the opening of the secondary throttle plate very closely and by making small adjustments to the primary throttle position could repeatable results be obtained during these three modes. The load changes associated with the slight change in primary throttle position were negligible, on the order of 1 percent of the observed power. This was well within the ±2 percent load tolerance in the 23-mode procedure.

Listed on Table 9 are the results of the duplicate 23-mode test results for the 1977 Chevrolet 366 engine (California version). Copies of the computer printouts are included in Appendix C as Tables C-9 and C-10. The 9-mode FTP g/bhp-hr results given in the L. V. Faix letter of December 15, 1976, were 23.05 CO, 0.77 HC and 4.16 NO_x. It is not possible to directly compare these results due to the gross differences in procedure, including loads, speeds, weighting factors and types of instruments for measurement.

4. Discussion

Figure 11 compares the average gaseous emissions and specific fuel consumption values for the Caterpillar 3208 EGR Diesel and Chevrolet 366 gasoline fueled engines. The comparison is on the same 23-mode EPA cycle and therefore is a direct comparison. To the extent that both engines are competitive in application, such as 2-axle vans, stakes and small 2-axle tractors, and to the extent both engines' emissions are fairly represented by the 23-mode test, some interesting differences are apparent.

First, the Diesel engine CO is about 1/8 of the gasoline engine CO, and the Diesel specific fuel consumption is about two-thirds of the gasoline engine. Both these findings were expected and continue to illustrate the superior fuel efficiency of the Diesel engine and its typically low CO emissions. Recall that the 1977 Chevrolet 366 (California version) was not equipped with an oxidation catalyst. For that matter, neither was the Diesel engine.

In terms of HC, NO_2 and HC+NO_2, the differences are mainly in HC being less with the Diesel engine. HC was about half the gasoline, while the Diesel NO_2 was slightly higher, about 10 percent, than the gasoline engine, 5.072 versus 4.56 g/kw-hr. It should be noted that the Caterpillar 3208 EGR HC emission rate of 1.783 g/kw-hr is fairly high relative to other HDD engines and may have been due to the use of EGR.

B. Smoke Results

Table 11 is a summary listing of the "a" acceleration, "b" lug-down and "c" peak opacity results of the Federal Smoke Test for HDD engines. Both the Mack and Caterpillar engines were subjected to these tests. The Chevrolet 366 engine, being gasoline fueled, was not. Shown at the bottom of Table 11 are the Federal limits for new engine certification beginning in calendar year 1970 and then reduced in 1974 with the addition of a peak limit.

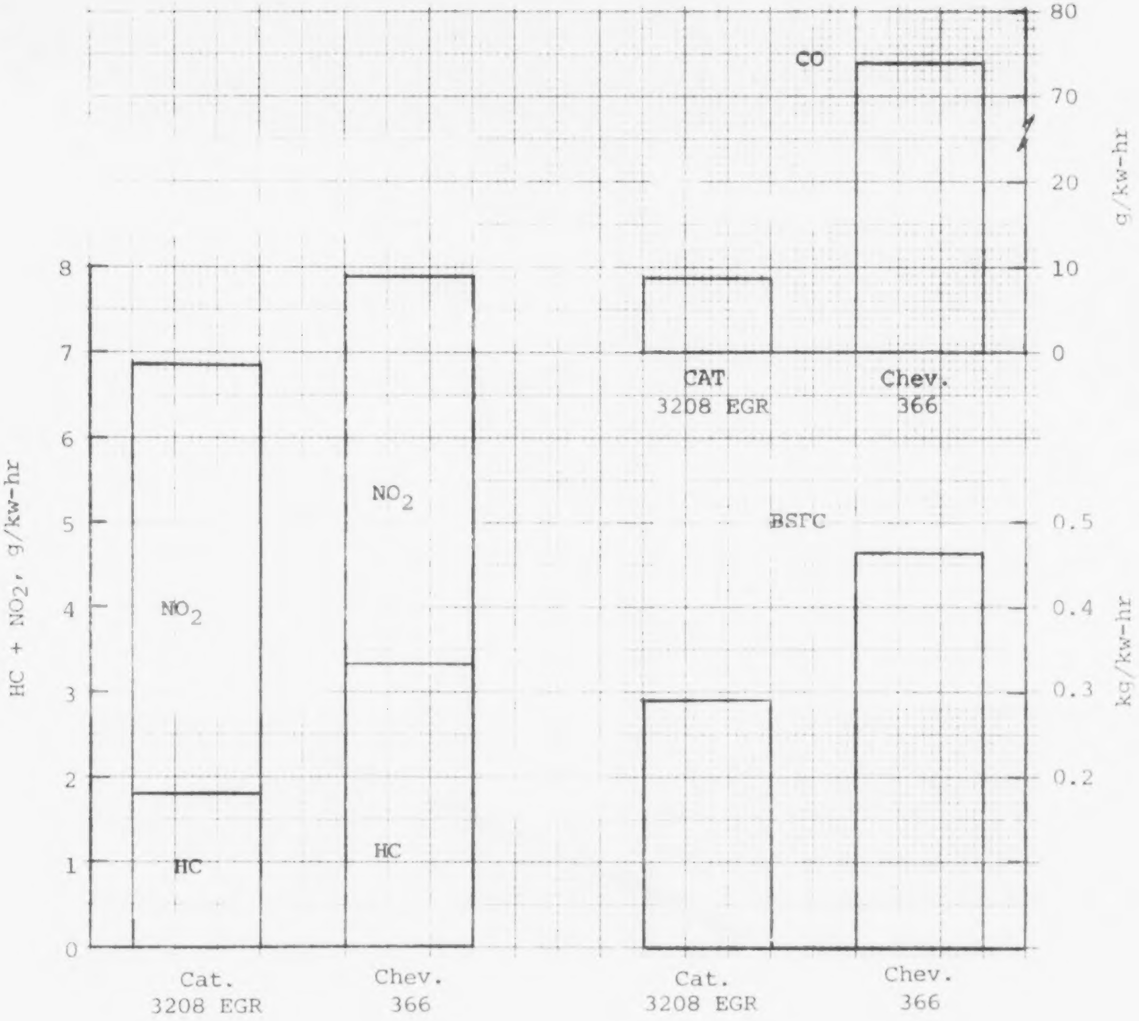


Figure 11. Comparison of Gaseous Emissions and Specific Fuel Consumption of Caterpillar 3208 EGR and Chevrolet 366 Engines (23-Mode EPA Test)

TABLE 11. FEDERAL SMOKE TEST RESULTS FOR MACK ETAY(B)673A AND CATERPILLAR 3208 EGR DIESEL ENGINES

Engine	Run	Smoke Factor, % Opacity		
		a (accel)	b (lug)	c (peak)
Mack	1	12.0	11.4	24.9
ETAY(B)673A	2	11.3	11.0	21.3
	3	11.2	11.4	21.4
	Average	11.5	11.3	22.5
1000-hr values		14.5	10.4	30.9
Caterpillar	1	10.1	8.7	21.3
3208 EGR	2	10.5	8.6	21.7
	Average	10.3	8.7	21.5
1000-hr values		8.0	7.2	21.5
Federal HD	1970	40	20	--
Limits	1974	20	15	50

1. Mack ETAY(B)673A

The smoke results on Table 11 agree quite well with the final 1000-hour certification values obtained in another SwRI laboratory on behalf of Mack as part of the certification process. Listed below are the smoke opacity readings taken during a full-power test at various engine speeds.

Engine rpm	Power kw obs	Smoke Opacity, % opacity		
		Run 1	Run 2	Average
1900	242.8	5.8	6.0	5.9
1700	243.6	6.8	8.3	7.6
1500	230.9	9.9	11.0	10.5
1450	226.6	10.7	12.5	11.6
1300	208.0	18.5	19.6	19.1

This engine operated at a derated engine speed of 1900 rather than normal 2100 rpm rated speed as one aspect of improved fuel economy features.

2. Caterpillar 3208 EGR

On completion of the third series of gaseous emissions tests described earlier, replicate Federal Smoke Tests were made. The results listed on Table 11 agree fairly well with those reported by Mr. Don Dowdall of Caterpillar for the 1000-hour test. These values also agree well with those initially obtained with the as-received engine even though a substantial amount of EGR system replacement, repair and readjustment took place in the meantime. The reason for this is that no EGR is allowed at full power and this is the demand on the engine throughout the Federal Smoke Test Cycle.

The modal smoke values obtained simultaneously with gaseous emissions are listed on Table 12. Note the 100 percent power smoke (no EGR) was 12 and 8.5 percent opacity at 1680 and 2800 rpm, respectively. The 75 percent power, modes 7 and 16, gave 8.3 and 17.3 percent opacity at 1680 and 2800 rpm, respectively. The EGR valve was part open to give a 15 percent EGR rate. The other modes of interest are modes 6 and 17, the 50 percent load points. At 1680 rpm the plume opacity was 5.3 percent, and at 2800 rpm the exhaust opacity was 22.6 percent. This was the highest smoke measured during the modal test and represents the open, 40 percent EGR condition. The 40, 15 and zero EGR rates are listed as defined by Caterpillar.

Usual operation of the dilution tunnel for particulate requires a sufficient exhaust flow into the tunnel to give as high a particulate loading as possible yet be below 125 degrees F at the filter face. On the assumption that both banks of the V-8 engine ran the same, the exhaust particulate loadings would be the same. This might allow measurement of particulate from just one bank at a time. To see if this approach would have merit, two smokemeters were used, one mounted on the left bank exhaust and the other on the right bank exhaust. Identical mountings were made with 76 mm (3-inch) diameter exhaust tubing at the ends of the exhaust.

Table 13 lists the results of a test made where exhaust backpressure on both banks of the engine were identical. Note that during all full-power operation, the left and right bank smoke is negligibly different, i.e., no more than about 1 percent opacity in a 10 percent opacity reading. However, when running at 75 or 50 percent power, the differences were dramatic. For example, at 75 percent load, the difference was 12.5 percent opacity (14.5 versus 2.0 percent) at 1680 rpm and 11 percent opacity (18.5 versus 7.5 percent) at 2800 rpm. The differences at 50 percent load were not as great but were still sufficient to discontinue the single bank exhaust particulate approach.

In analyzing the results of this experiment, it appears that the "recycle path" favors the left bank of the engine. Although the exhaust, as it reenters the engine intake, is apparently free to mix and reenter both banks of the engine, more may go to the left (EGR) side of the engine. If this is the case, it is possible that more of the exhaust enters one or two cylinders more than the others. Assuming this type of unequal distribution exists in this engine, then this would explain why the engine was so supersensitive to EGR.

Several years earlier, SwRI performed EGR experiments with an early system design for a similar Caterpillar engine.(45) Probably the most important part of the design was the EGR-intake air mixer. As a result, the sensitivity problems associated with the present experiments were not experienced except when excessive levels of EGR were used. These results, though not a part of the required test plan, are provided to help partially explain why the extremely high and variable CO, smoke and HC were encountered earlier when the valve was malfunctioning more or less.

C. Particulate and Sulfate Results

Particulate and sulfate results share a common sampling basis, the dilution tunnel system. Table 14 is a summary listing of the particulate and sulfate emission rates for the three HD engines tested. General methods of expressing

TABLE 12. SMOKE MEASURED DURING MODAL TESTING
(Caterpillar 3208 with EGR)

Mode No.	Engine Speed, rpm	Engine Power,%	EGR Valve		Smoke, % Opacity		
			Rate,%	Position(1)	Run 1	Run 2	Run 3
1	Idle	0	40	open	1.1	1.0	1.1
2	1680	2	40	open	1.0	1.0	1.0
3	1680	8	40	open	1.1	1.1	1.1
4	1680	18	40	open	1.2	1.5	1.4
5	1680	25	40	open	1.5	1.9	1.7
6	1680	50	40	open	5.0	5.5	5.3
7	1680	75	15	part	8.0	8.5	8.3
8(2)	1680	82	0	closed	1.2	2.1	1.7
9	1680	92	0	closed	2.8	3.9	3.4
10		100	0	closed	12.0	12.0	12.0
11	Idle	0	40	open	0.4	0.4	0.4
12	1680	CT	40	open	(5)	(5)	(5)
13	2800	100	0	closed	8.5	8.5	8.5
14	2800	92	0	closed	4.8	6.0	5.4
15(2)	2800	82	0	closed	3.3	4.5	3.9
16(3)	2800	73	15	part	15.0	19.5	17.3
17(4)	2800	48	40	open	21.2	23.9	22.6
18	2800	25	40	open	9.5	10.5	10.0
19	2800	18	40	open	7.0	7.5	7.3
20	2800	8	40	open	4.5	4.1	4.3
21	2800	2	40	open	4.0	3.8	3.9
22	Idle	0	40	open	1.5	0.4	1.0
23	2800	CT	40	open	(5)	(5)	(5)

---

(1) Position relates to the general rotation of the valve to preset openings.

(2) Achieved by manual signal to valve positioner to "closed" position since 82% load is transition point of automatic system.

(3) Operated at 73% instead of 75% power to give less variable emissions.

(4) Operated at 48% instead of 50% power to give less variable emissions.

(5) Smoke data not taken during closed throttle.

TABLE 13. CATERPILLAR 3208 EGR LEFT AND RIGHT BANK SMOKE LEVELS

			Smoke Opacity,%		Backpres.,mm Hg	
Mode No.	Engine rpm	Power Percent	Left Bank	Right Bank	Left Bank	Right Bank
1	600	---	0.5	0.5	1.3	1.3
2	1680	2	0.8	0.8	5.1	5.1
3	1680	25	0.6	0.4	5.1	5.1
4	1680	50	6.5	1.4	5.1	5.1
5	1680	75	14.5	2.0	7.6	7.6
6	1680	100	11.0	9.5	24.1	24.1
7	600	---	0.4	0.4	1.3	1.3
7a	1680	CT	0.0	0.0	5.1	5.1
8	2800	100	6.0	5.9	62.2	62.2
9	2800	75	18.5	7.5	27.9	27.9
10	2800	50	20.5	14.0	12.7	12.7
11	2800	25	9.0	7.0	10.2	10.2
12	2800	2	3.4	2.4	10.2	10.2
13	600	---	0.6	0.5	1.3	1.3
Maximum Power Curve						
	2800		6.0	5.5	62.2	62.2
	2400		5.6	4.1	47.0	47.0
	2000		7.1	6.5	36.8	36.8
	1600		15.5	12.5	24.1	24.1
	1200		25.0	24.0	12.7	12.7

Note: Left and right banks both set at 63.5 mm Hg (2.5 inches Hg) at 2800 rpm, 100% load. 13-mode cycle was run leaving left (EGR side) restrictor at original setting and resetting right restrictor to match the backpressure of the left bank.

TABLE 14. SUMMARY OF PARTICULATE AND SULFATE EMISSION RATES
(Based on 47 mm Fiberglass and Fluoropore Samples)

Operating Condition	Engine Make Model	Particulate Rates					Sulfate Rates			$SO_4^=$ Recovery %
		mg/m³	g/hr	g/kg fuel	g/kw-hr	µg/m³	mg/hr	mg/kg Fuel	mg/kw-hr	
Inter Speed 2% Load	Mack ETAY	23.04	10.57	2.28	2.25	932.3	427.4	92.4	90.9	1.31
	Cat 3208	52.42	16.16	4.15	7.70	681.4	210.5	53.98	100.24	0.77
	Chev 366	20.41	1.72	0.40	1.91	ND	---	---	---	---
	Alt(1)					236.7	19.9	4.53	22.13	0.50
Inter Speed 25% Load	Mack ETAY	61.39	33.51	2.48	0.58	4433.1	2419.7	176.8	41.7	2.51
	Cat 3708	57.98	17.55	2.14	0.62	1559.7	471.9	57.90	16.62	0.82
	Chev 366	18.01	1.96	0.31	0.18	0.97	0.105	0.017	0.010	0.002
	Alt(1)					188.9	20.5	3.26	1.92	0.36
Inter Speed 50% Load	Mack ETAY	118.49	84.41	3.41	0.75	6574.1	4689.6	189.0	41.3	2.69
	Cat 3208	189.80	54.34	4.03	0.96	2975.0	852.9	63.31	15.02	0.90
	Chev 366	22.49	3.04	0.36	0.14	2.35	0.317	0.037	0.015	0.004
	Alt(1)					261.9	35.3	4.16	1.64	0.46
Inter Speed 75% Load	Mack ETAY	146.91	132.84	3.66	0.77	6993.0	6343.1	174.4	36.6	2.48
	Cat 3208	303.71	110.22	5.62	1.29	3789.7	1375.8	70.19	16.15	1.00
	Chev 366	40.19	6.87	0.60	0.22	2.81	0.480	0.042	0.015	0.005
	Alt(1)					472.7	80.8	7.02	2.52	0.78
Inter Speed 100% Load	Mack ETAY	254.55	260.76	5.40	1.11	9576.3	9813.0	202.5	41.7	2.88
	Cat 3208	483.03	215.83	8.43	1.90	3581.4	1600.3	62.52	14.07	0.89
	Chev 366	49.36	10.07	0.60	0.24	5.01	3.770	0.227	0.090	0.025
	Alt(1)					642.4	131.0	7.84	3.12	0.87
Idle	Mack ETAY	13.83	2.55	3.76	---	948.9	174.4	244.3	---	3.47
	Cat 3208	37.64	4.60	5.11	---	1671.3	201.7	237.72	---	3.37
	Chev 366	26.49	1.28	0.53	---	8.44	0.406	0.176	---	0.019
	Alt(1)					279.9	13.5	5.38	---	0.60
Inter Speed Cut Throttle	Mack ETAY	This mode not run								
	Cat 3208	66.73	21.85	---	---	805.7	264.1	---	---	---
	Chev 366	30.79	1.87	0.75	---	46.06	2.789	1.105	---	0.120
	Alt(1)					309.2	18.7	7.20	---	0.80
High Speed 100% Load	Mack ETAY	135.30	191.8	3.40	0.76	8854.1	12554.5	222.2	49.7	3.15
	Cat 3208	378.19	252.31	6.69	1.75	5232.7	3494.6	92.82	24.25	1.32
	Chev 366	63.54	26.09	0.77	0.30	211.44	86.814	2.551	0.991	0.278
	Alt(1)					1602.6	658.0	19.5	7.49	2.16
High Speed 75% Load	Mack ETAY	97.61	120.11	2.77	0.63	6535.6	8036.6	185.5	41.9	2.63
	Cat 3208	1232.82	648.50	21.06	6.21	3152.7	1657.5	53.89	15.88	0.77
	Chev 366	50.28	16.32	0.70	0.25	682.54	221.560	9.448	3.349	1.028
	Alt(1)					1506.1	488.9	20.81	7.36	2.31

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(1) Alternate Chevrolet 366 sulfate results based on reanalyzed IPA solutions performed on 11/1/77, 9 weeks after initial analysis.

TABLE 14 (CONT'D). SUMMARY OF PARTICULATE AND SULFATE EMISSION RATES
(Based on 47 mm Fiberglass and Fluoropore Samples)

Operating Condition	Engine Make Model	Particulate Rates mg/m^3	g/hr	g/kg fuel	g/kw-hr	μg/m^3	Sulfate Rates mg/hr	mg/kg Fuel	mg/kw-hr	$SO_4^=$ Recovery %
High	Mack ETAY	84.23	82.43	2.80	0.67	5985.5	5852.2	198.5	47.1	2.82
Speed	Cat 3208	919.73	383.07	17.18	5.50	4152.8	1728.5	77.51	24.83	1.10
50%	Chev 366	23.88	6.12	0.35	0.14	59.42	1.859	0.105	0.042	0.012
Load	Alt$^{(1)}$					603.0	154.4	8.73	3.46	0.97
High	Mack ETAY	71.70	54.20	3.17	0.87	4371.9	3304.15	192.9	53.2	2.74
Speed	Cat 3208	302.18	133.46	9.20	3.69	3954.5	1744.0	120.24	48.18	1.71
25%	Chev 366	24.81	4.78	0.40	0.22	---	---	---	---	---
Load	Alt$^{(1)}$					526.3	101.4	8.46	4.63	0.94
High	Mack ETAY	39.01	23.94	3.32	4.83	1378.5	846.0	117.3	170.3	1.67
Speed	Cat 3208	127.07	57.01	6.33	20.36	1734.5	778.3	86.97	277.96	1.23
2%	Chev 366	14.77	2.10	0.30	1.24	---	---	---	---	---
Load	Alt$^{(1)}$					237.8	33.7	4.82	19.83	0.54
High	Mack ETAY	This mode not run								
Speed	Cat 3208	70.25	28.67	---	---	396.9	161.1	---	---	---
Cut	Chev 366	25.16	2.79	0.65	---	68.78	7.614	1.781	---	0.194
Throttle	Alt$^{(1)}$					192.3	21.3	4.95	---	0.55

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(1) Alternate Chevrolet 366 sulfate results based on reanalyzed IPA solutions performed on 11/1/77, 9 weeks after initial analysis.

the rate of emission for each contaminant are listed as follows: first, the concentration, in mg/m^3 or μg/m^3, for particulate and sulfates; then a mass per unit of time, g/hr, rate; then two specific mass emission rates, g or mg per kg fuel consumed and g or mg per kw-hr of work produced. These are commonly known as "fuel specific" and "brake specific" emission rates. Also listed on Table 14 are percent fuel sulfur converted to sulfate.

Table 15 is a summary of the engine operating conditions measured during the sampling for particulate and sulfate. The values are averaged for the replicate tests and may be used to represent typical operation. For example, the fuel rate or air flow rate may be used in determining emissions per day given a usage factor, cycle of operation and the emission rates of Table 14. For purposes of additional discussion, the results are graphed first for the Mack and then for comparison of the Caterpillar 3208 EGR Diesel to the Chevrolet 366 gasoline.

1. Mack ETAY(B)673A

Figures 12 and 13 are graphs of average particulate and sulfate rates, given in Table 14 for the Mack engine. The rates are plotted against power level at the rated and intermediate engine speeds. From Figure 12, the particulate rate, g/hr, increased linearly up to 75 percent of power. At full power, the particulate rate increased at a higher than linear rate. The usual g/hr behavior for particulate from Diesel engines is to increase linearly or nearly so as power is increased.

Sulfate rates on Figure 13 show a similar trend, in mg/hr, to the particulate. A nearly linear increase in sulfate is shown to 75 percent power and then a slightly increasing rate at 100 percent power. Sulfate from Diesels has been shown to be mainly a function of the fuel consumed. The sulfur in the sulfate, as a percent of the fuel sulfur burned, ranged from about 1.3 to 3.2 percent with an average of 2.4 percent based on the data in Table 14.

Figure 14 is a graph of the principal engine conditions of power output, fuel rate and air flow of the Mack ETAY(B)673A engine. These data are from Table 15. They are averages of values observed during this series of tests.

2. Caterpillar 3208 EGR

Knowing the extreme sensitivity of the EGR system to exhaust backpressure, it was decided to take special precautions when operating this engine with the dilution tunnel. Recall that the dilution tunnel used in these tests can only dilute a portion of the engine's exhaust, not the entire flow. Normally, the flow obtained from the exhaust muffler is regulated by adjusting the backpressure on the muffler and engine to force more or less of the sample out of the muffler and into the tunnel. For this engine, which has a limit of 63.5 mm Hg (2.5 inches Hg) at 2800 rpm, maximum power, the engine backpressures measured during a 13-mode FTP are shown on Table 16. All particulate samples were obtained at engine backpressures adjusted in accord with the values listed in Table 16.

This required the use of several size, diameter, muffler inserts to be able to obtain sufficient sample at the very low backpressures at idle and

TABLE 15. SUMMARY OF ENGINE OPERATING CONDITIONS 47 mm GLASS AND FLUOROPORE FILTER TESTS

Condition Speed/ Load %	Engine(1)	Engine Speed rpm	Power Out kw	Fuel Rate kg/hr	Air Rate kg/min	BSFC kg fuel kw hour	Inlet Air °C	Inlet Rest mm Hg	Exh. Rest mg Hg
Inter/02	Mack	1450	4.70	4.65	9.1	0.989	24	10.1	25.4
	Cat	1680	2.10	3.90	6.1	1.857	29	12.9	5.1
	Chev	1200	0.9	4.4	1.7	4.833	34	32.7	2.8
Inter/25	Mack	1450	58.0	13.6	10.4	0.234	24	12.1	27.9
	Cat	1680	28.4	8.15	5.9	0.287	27	12.1	5.1
	Chev	1200	10.7	6.3	2.2	0.589	40	25.6	25.4
Inter/50	Mack	1450	113.7	24.8	13.1	0.218	26	17.0	26.7
	Cat	1680	56.8	13.4	5.5	0.236	26	11.0	4.2
	Chev	1200	21.5	8.5	2.7	0.395	37	18.0	5.6
Inter/75	Mack	1450	173.4	36.4	16.5	0.210	25	23.8	27.9
	Cat	1680	85.2	19.6	7.0	0.230	29	15.9	8.9
	Chev	1200	32.0	11.5	3.4	0.359	36	9.5	7.6
Inter/100	Mack	1450	235.4	48.3	19.8	0.205	26	31.5	43.2
	Cat	1680	113.7	25.6	8.5	0.225	28	22.4	18.4
	Chev	1200	42.0	16.7	4.1	0.398	45	0.56	12.7
Idle	Mack	620	----	1.0	3.66	-----	24	3.7	25.4
	Cat	600	----	0.8	2.42	-----	30	3.0	----
	Chev	750	----	2.5	1.0	-----	40	31.2	0.8
Inter/CT	Mack	1450	----	----	----	-----	--	----	----
	Cat	1680	----	----	6.5	-----	27	14.4	----
	Chev	1200	----	2.5	1.2	-----	39	39.1	0.3
High/100	Mack	1900	252.2	56.2	27.0	0.224	23	46.7	57.2
	Cat	2800	143.9	37.6	12.7	0.261	29	47.4	61.3
	Chev	2300	87.7	33.8	8.2	0.385	35	1.2	59.7
High/75	Mack	1900	191.4	43.4	23.7	0.227	25	39.5	50.8
	Cat	2800	104.4	30.6	10.0	0.293	30	29.7	34.3
	Chev	2300	66.4	23.5	6.5	0.354	40	10.5	38.1
High/50	Mack	1900	124.5	29.5	18.7	0.237	24	27.8	40.6
	Cat	2800	69.6	22.3	8.0	0.320	31	20.5	22.9
	Chev	2300	44.6	17.7	5.1	0.397	44	19.0	22.2
High/25	Mack	1900	62.1	17.2	14.8	0.277	24	19.2	25.4
	Cat	2800	36.2	14.5	8.6	0.401	26	22.4	18.4
	Chev	2300	21.9	12.0	3.9	0.548	44	28.5	8.9
High/02	Mack	1900	4.95	7.2	12.2	1.45	24	14.1	25.4
	Cat	2800	2.8	8.95	8.9	3.20	30	24.3	15.2
	Chev	2300	1.7	7.0	2.8	4.12	35	35.8	5.1
High/CT	Mack	1900	----	----	----	----	--	----	----
	Cat	2800	----	----	8.1	----	27	20.7	25.4
	Chev	2300	----	4.3	2.2	----	42	40.9	1.3

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(1) Mack ETAY(B)673A, Caterpillar 3208 EGR, Chevrolet 366

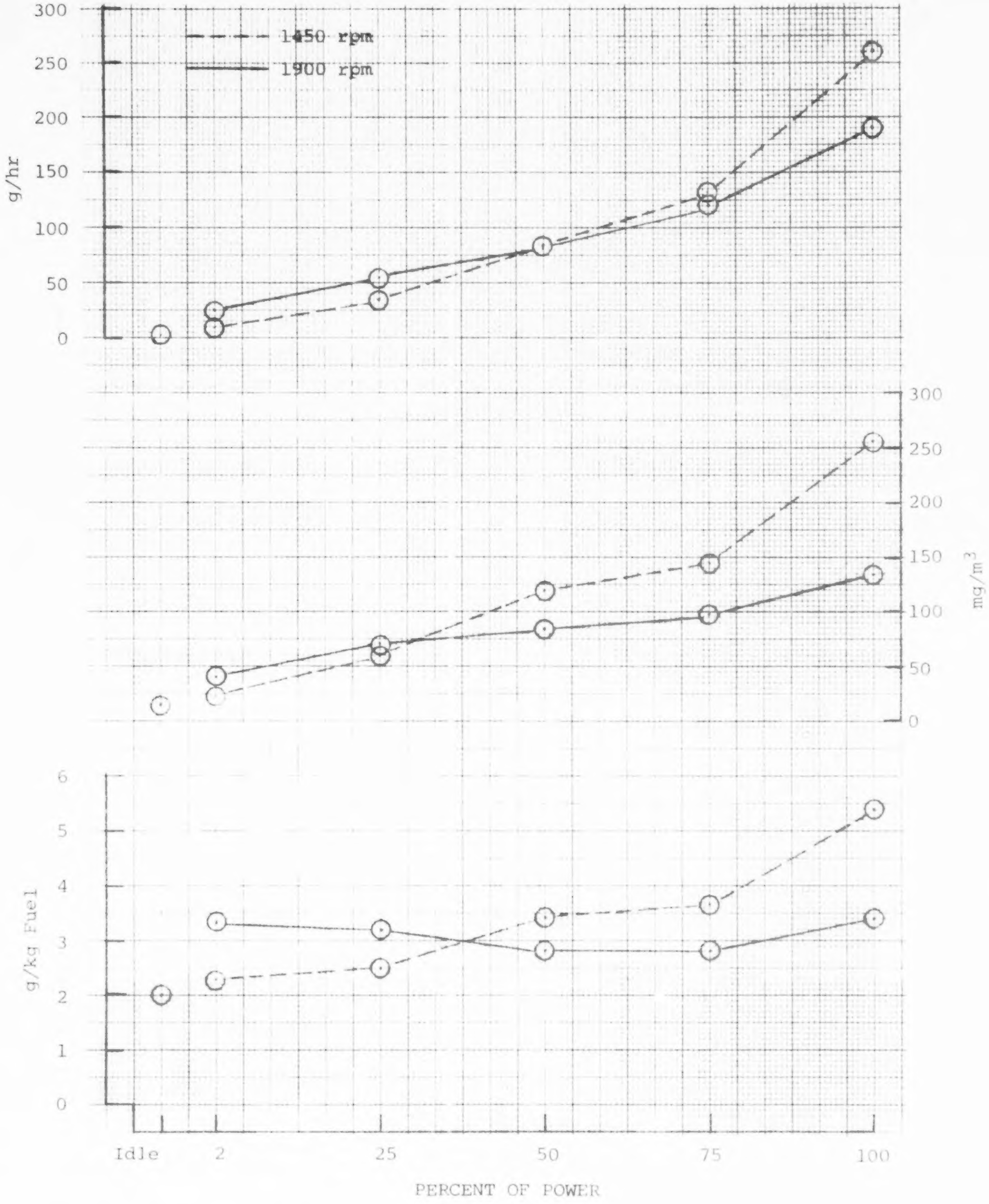

Figure 12. Particulate Emission Rates from Mack ETAY(B)673A Truck Engine, Based on 47 mm Glass Filters

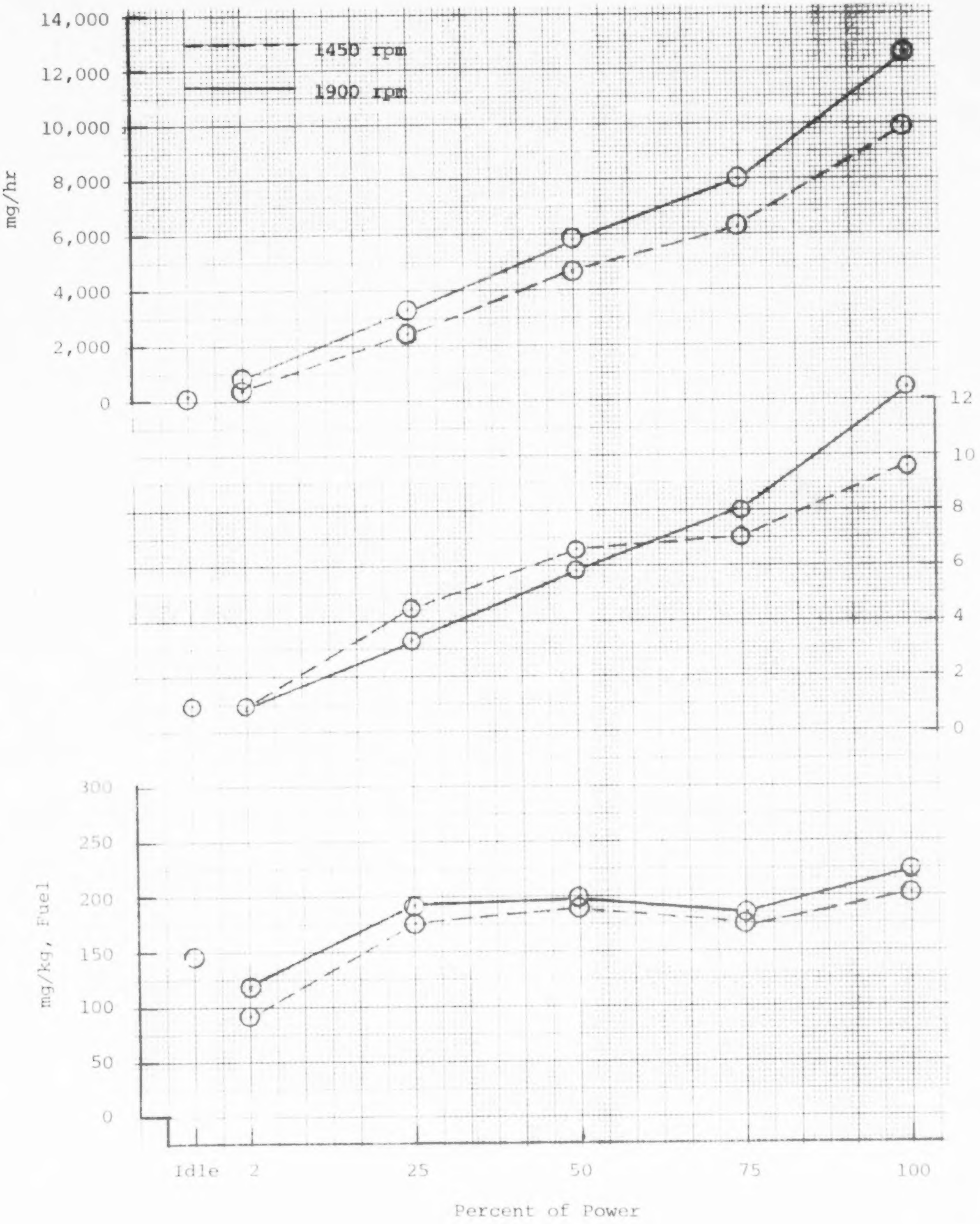

Figure 13. Sulfate ($SO_4^=$) Emission Rates from Mack ETAY(B)673A Truck Engine, Based on 47 mm Fluoropore Filters

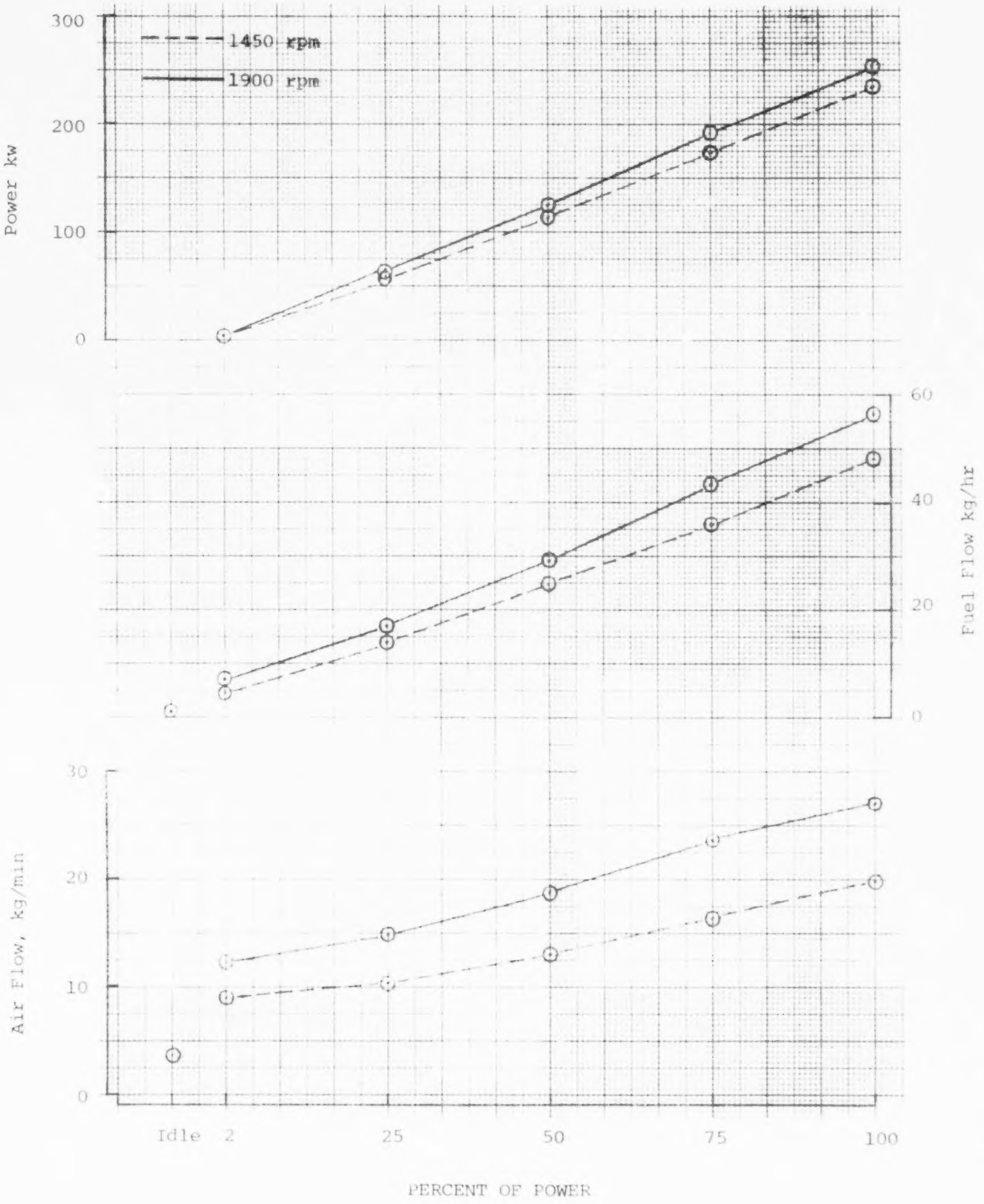

Figure 14. Power Output, Fuel and Air Fates from Mack ETAY(B)673A Truck Engine

TABLE 16. EXHAUST BACKPRESSURE SCHEDULES - CATERPILLAR 3208 EGR

Mode No.	Engine rpm	Power Percent	Engine Exhaust Backpressure 13 Mode FTP[1] mm Hg	in. Hg
1	600	---	0.8	0.03
2	1680	2	2.5	0.1
3	1680	25	5.1	0.2
4	1680	50	5.1	0.2
5	1680	75	7.6	0.3
6	1680	100	17.8	0.7
7	600	---	0.8	0.03
8	2800	100	63.5	2.5
9	2800	75	35.6	1.4
10	2800	50	22.9	0.9
11	2800	25	20.3	0.8
12	2800	2	15.2	0.6
13	600	---	0.8	0.03

---

(1) Based on preset 63.5 mm Hg (2.5 inches Hg) at 2800 rpm and full load.

the 1680 rpm conditions. This extra care was essential to ensure that the engine operated just the same as it would during a normal 13-mode FTP gaseous emissions test. The sulfate and particulate results thus obtained are listed in Table 14. They will be discussed in detail in a later subsection.

3. Chevrolet 366

This was the first opportunity to measure particulate and sulfate emissions from a HDG engine. The engine was operated with the regular grade gasoline containing 1.6 g/gal lead described in a previous section. The same dilution tunnel as was used for the Mack ETAY(B)673A and Caterpillar 3208 EGR engines was employed. It received a thorough cleaning and recalibration, however, prior to its use on the gasoline engine. A new muffler of the type used with a Chevrolet C-50 or C-60 size truck was obtained and modified to split a suitable sample from the muffler outlet cavity.

A temperature not to exceed 110°F at the filter face was maintained in keeping with the more volatile aspects of gasoline engine exhaust products and particulate. It was found that the usual 10 to 20 minute sampling period had to be greatly extended to accumulate sufficient particulate on the filter disc for analysis. This first test of the HDG engine particulate required substantial attention to detail to gain satisfactory results. The results are listed in Table 14 and are discussed in the next subsection.

4. Discussion of Caterpillar 3208 and Chevrolet 366 Results

Figure 15 is a plot of the three particulate emission rates, g/hr, g/m^3, and g/kg fuel, for both engines. The first item of importance is the quite different behavior of the Caterpillar 3208 EGR engine at rated, 2800 rpm, and intermediate, 1680 rpm. This is quite apparent by all three graphs or ways of expressing the particulate emission rate.

For example, the increase in g/hr is smooth and continuous at 1680 rpm and not unlike Diesel engine behavior. At 2800 rpm, the particulate rate increased very rapidly with power reaching a peak of 650 g/hr at 75 percent power before decreasing to 252 g/hr at full power. Recall that no EGR is scheduled at the 100 percent or full-power operating level. For the Caterpillar 3208 EGR engine, data were also acquired under closed throttle (CT) conditions of motoring at 2800 and 1600 rpm. The CT rates were very similar to the 2 percent power levels.

Compared to the Diesel, the Chevrolet 366 gasoline engine produced far less particulate. For example, the Diesel engine produced on the order of 20 times the g/hr particulate rate of the gasoline. The Diesel engine was more powerful also, and this is one reason for the large difference in rates given in the top set of curves in Figure 15. The gasoline particulate rates were quite uniform and consistent, indicating a slight increase in rate with an increase in power.

Figure 16 is similar to Figure 15, except it is a comparison of the sulfate emission rates for both engines. It is interesting to compare the Caterpillar 3208 sulfate rates on Figure 16 to the particulate rates on Figure 15. At the 1680 rpm intermediate speed, the sulfate rate increased as expected with power level, mainly due to an increase in the fuel burned per hour or fuel rate. At 2800 rpm, the increase with power (fuel rate) was evident by the 2, 25 and 100 percent power points. However, it is as if the EGR and large increases in total particulate measured at 50 and 75 percent of power (shown on Figure 15) had the effect of reducing sulfate production at those two points.

The sulfate levels measured during cut throttle need some explanation. This mode had never been measured on a Diesel engine at SwRI before these experiments. The mg/hr rates are low, as they should be for a motoring condition in which the fuel rate is essentially zero. This is the reason that mg/kg fuel and the percent fuel sulfur converted to sulfate were not computed and are not included on Table 14. Under essentially zero fuel injection, the question of where the sulfate measured on the filters came from is uncertain.

Based on a fuel sulfur content of 0.235 (EM-272-F), the sulfate production of the Caterpillar 3208 EGR was about 1.25 percent of the sulfur in the fuel on the average. The recoveries ranged from about 0.8 to 3.23 percent. This is in keeping with the previous findings of 1-3 percent of the fuel sulfur converted to that which is measured as sulfur in the sulfate by the BCA procedure. It is about half that of the Mack ETAY(B)673A engine previously discussed.

The Chevrolet 366 sulfate results posed an entirely new set of circumstances than previously run Diesel and gasoline engines. During a November 7, 1977, visit to SwRI by the Project Officer, the problems encountered in measuring sulfate from the Chevrolet 366 were discussed. At the heart of the

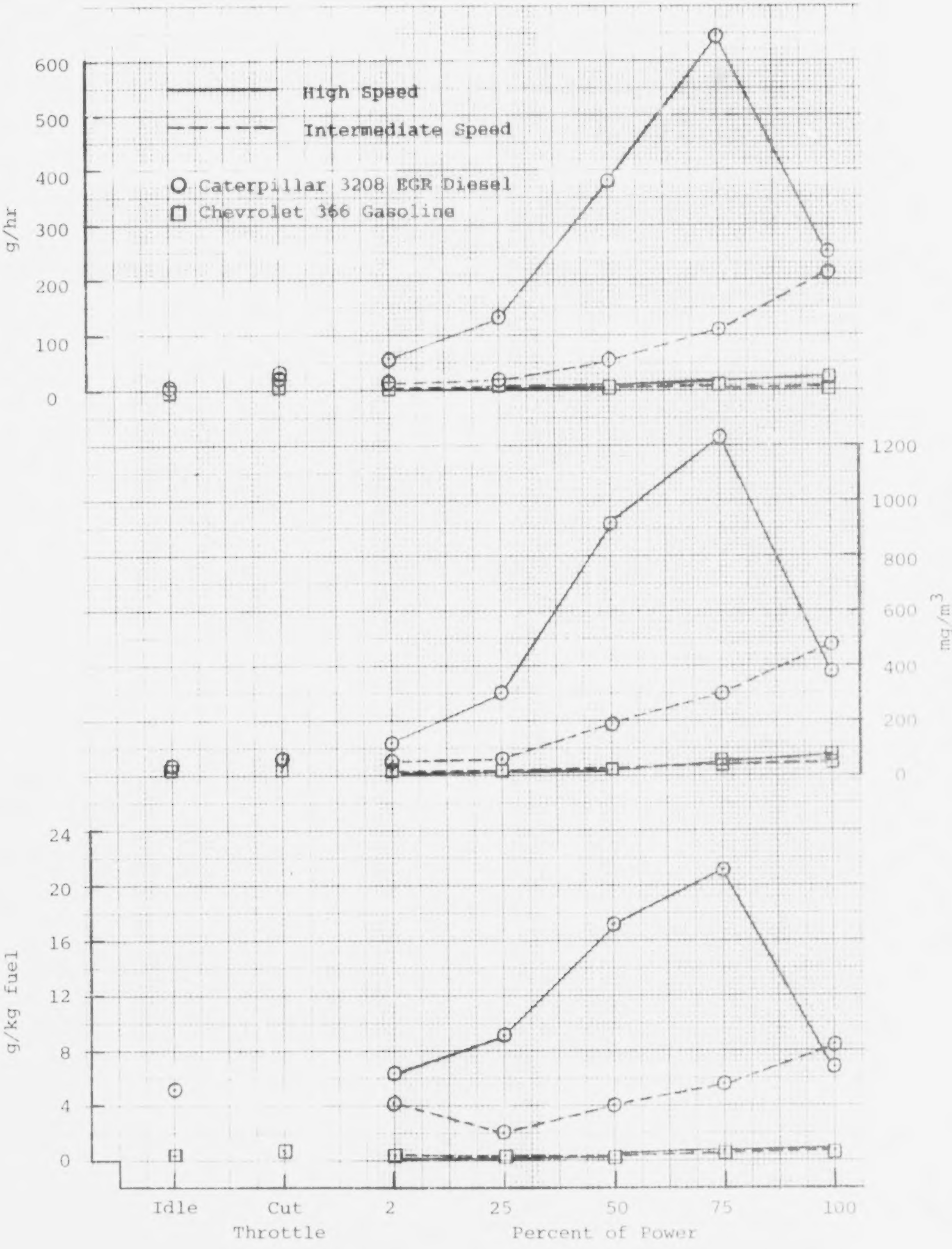

Figure 15. Particulate Emission Rates from Caterpillar 3208 and Chevrolet 366 Truck Engines Based on 47 mm Glass Filters

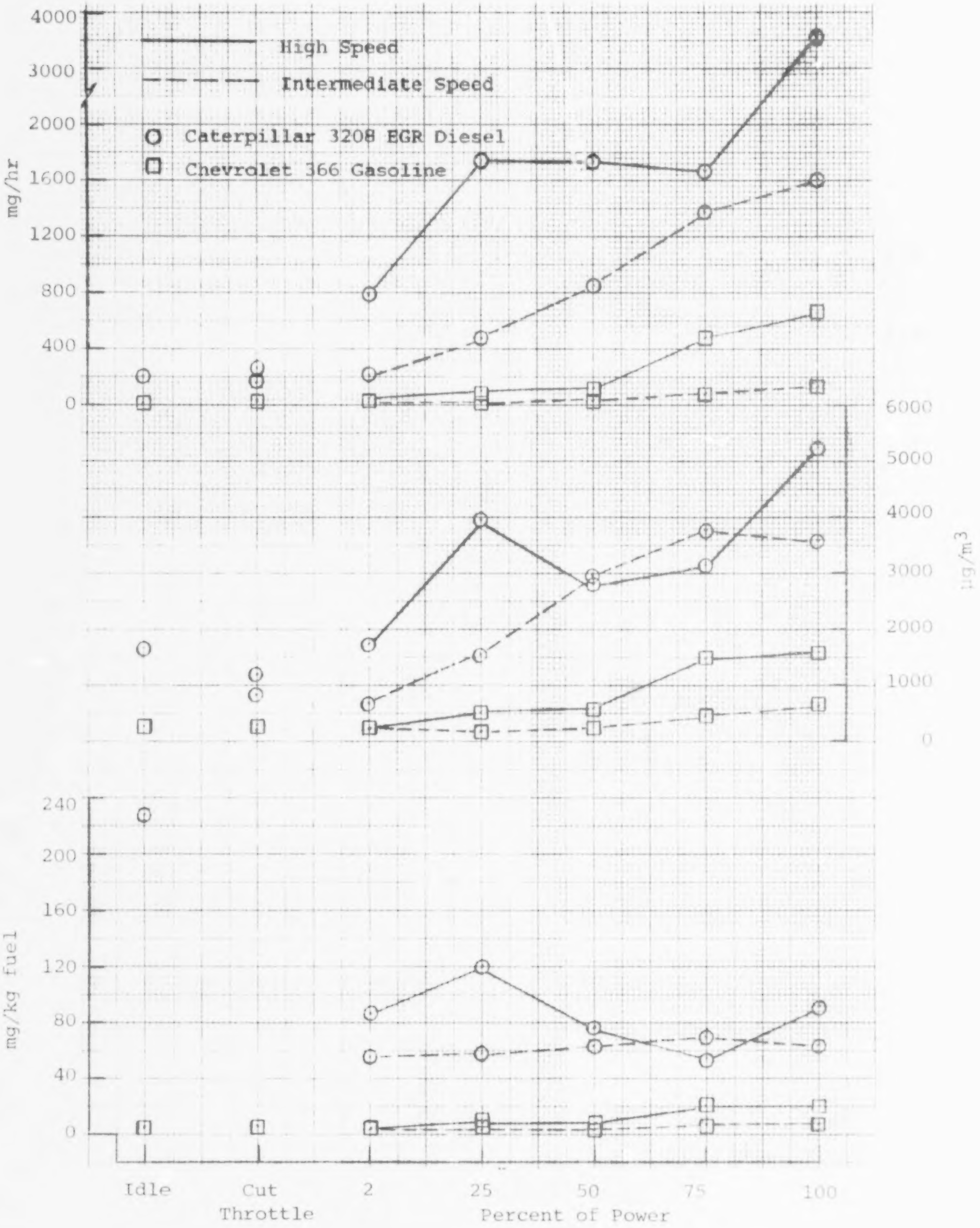

Figure 16. Sulfate ($SO_4^=$) Emission Rates from Caterpillar 3208 and Chevrolet 366 Truck Engines, Based on 47 mm Fluoropore Filters

problem was the difficulty of measuring sulfate from a gasoline engine operating on leaded gasoline. This is not normally done and historically was not possible due to positive interferences in the BCA analysis of the combustion products of the lead scavenger compounds (chlorine and bromine based compounds). The use of a silver nitrate column in the BCA analysis had remedied this and was not the phenomenon experienced.

Following the normal sulfate collection on Fluoropore filters, the filters were ammoniated, weighted, put into the isopropyl alcohol (IPA) solution and analyzed by the BCA procedure. The results were, with only a few exceptions, extremely low, so low that the detection peak was below the minimum needed to trigger the computer to integrate the peak. These very, very low initial results were of great concern. The IPA solutions of one run were reanalyzed with the same low results obtained.

About nine weeks later, it was decided to rerun not only the IPA solutions which gave the very low values but to analyze the remaining duplicate Fluoropore filters which had already been ammoniated but not put into the IPA solution. This was done with the net effect of all values being much higher and fairly repeatable. Such a result would cause suspicion of the initial results. However, the initial results were performed properly, and, on re-analyzing the strip charts, calibrations, range and calculations, nothing could be found to fault those initial values.

Discussions with Mr. Frank Black and Dr. Silvestre Tejeda of EPA, RTP, were unable to result in reasons for the very low values or the apparent change. SwRI chemists were also unable to offer more than mere speculation. There is an apparent lack of knowledge of how to use the BCA procedure with leaded fuel. Nearly all sulfate testing has been with unleaded fuel. Thus, a mystery continues on this point and no simple explanation seems possible at this time. In agreement with the Project Officer, both sets of values will be reported and documented.

Table 14 lists two sets of sulfate data, the first set being an average of the two runs that gave the extremely low values. Exceptions to this were the high speed (2500 rpm) 75 and 100 percent load points where sulfate accounted for 0.03 and 0.28 percent of the fuel sulfur, respectively. The two cut throttle conditions, with very low fuel rates, gave 0.12 percent (intermediate speed) and 0.194 percent (high speed of 2300 rpm) sulfur conversion to sulfate. The remaining idle and power conditions produced very low sulfate levels, commonly amounting to less than 0.01 percent of the fuel sulfur.

Listed below the initial BCA analysis is the average of the reanalysis made on November 1, 1977, some nine weeks after the initial BCA evaluations. The reanalysis was made of the original IPA solutions. These solutions had been tightly capped and suitably stored for such eventuality. The averages represent good run-to-run repeatability, except a few conditions, and this is surprising for a gasoline engine where sulfate is normally emitted as sulfuric acid mist and is prone to storage and purge (release) from the exhaust system. The average values, summarized on Table 14, are substantially higher than the initial analysis. Sulfate recovery, as a percent of the fuel sulfur, ranges from 0.36 up to 2.31 percent with an overall average of 0.91 percent.

It is not certain which set of analyses is proper since this is the first opportunity known to attempt the measurement of sulfate from a HDG engine operating on a fuel containing 1.6 g/gal lead. It can be argued that the first set of measurements is correct, but obviously the BCA method is inappropriate for use with leaded fuels. The reanalysis of the original IPA solutions, and their confirmation by analysis of the duplicate filter some nine weeks after its collection and ammoniation, indicates that a non-negligible level of sulfate, or what the BCA procedure indicates as sulfate, was collected. Other evidence pointing to the possibility of the reanalyzed values being appropriate is the non-negligible initial rate obtained at 75 and 100 percent power, 2300 rpm.

For purposes of discussion and preliminary comparison, the reanalyzed results from Table 14 alternate (1) for the Chevrolet 366 engine are plotted on Figure 16. The rates are quite uniform and consistent, showing an increase in mg/hr and $\mu g/m^3$ with power for the 2300 rpm and only a slight increase for the 1200 rpm speed. The higher speed condition, as expected, resulted in higher mg/kg and concentration. The effect of speed on the mg/kg fuel was negligible, meaning that the sulfate, or the BCA reanalyzed IPA solutions, was essentially a common or constant rate of the amount of fuel consumed.

Table 14 contains the averages of the two runs, sometimes slightly rounded, that are listed in Appendix C. Tables C-11 and C-12 are the particulate and sulfate tables for the Mack ETAY(B)673A engines. Tables C-13 and C-14 are the particulate and sulfate listings for the Caterpillar 3208 EGR engine. Table C-15 lists the particulate rates for the Chevrolet 366 engine. The sulfate rates are listed on Table C-16 for the initial analyses that were mostly negligible, while Table C-17 gives the results of the reanalysis of the initial IPA sulfate solutions. Also listed on Table C-17 are the results of the analysis of the run 2, spare filter which was taken as backup during the original engine operation. As a matter of routine, these filter samples were ammoniated and placed in sealed plastic containers until they were placed in IPA solution for BCA analysis.

Figure 17 illustrates the fuel rate, observed power output and air flow of both the Caterpillar 3208 EGR and Chevrolet 366 engines. The Caterpillar test conditions were such as to produce nearly twice the power output as that of the Chevrolet 366. The fuel rate was higher for the gasoline engine per unit of power produced, as mentioned earlier in the cycle BSFC values for gaseous emissions. For more complete engine data, see Table 15.

5. Cycle Composite Particulate and Sulfate

The modal particulate and sulfate data presented and described earlier may be computed as a cycle composite value. Depending on what weighting factors are used, the modal data can be used to simulate various types of duty cycles. All engines were run on the eleven different modes of the 13-mode FTP, and thus a 13-mode cycle composite may be computed using the usual 13-mode FTP weighting factors. In addition, the Caterpillar 3208 EGR and Chevrolet 366 ran two cut throttle modes permitting a cycle composite based on weighting factors derived from the EPA 23-mode procedure. The basis for these weighting factors was described in Section III of this report.

Table 17 is a summary listing of the cycle composite values using 13-mode FTP weighting factors and factors derived from the 23-mode test. Both

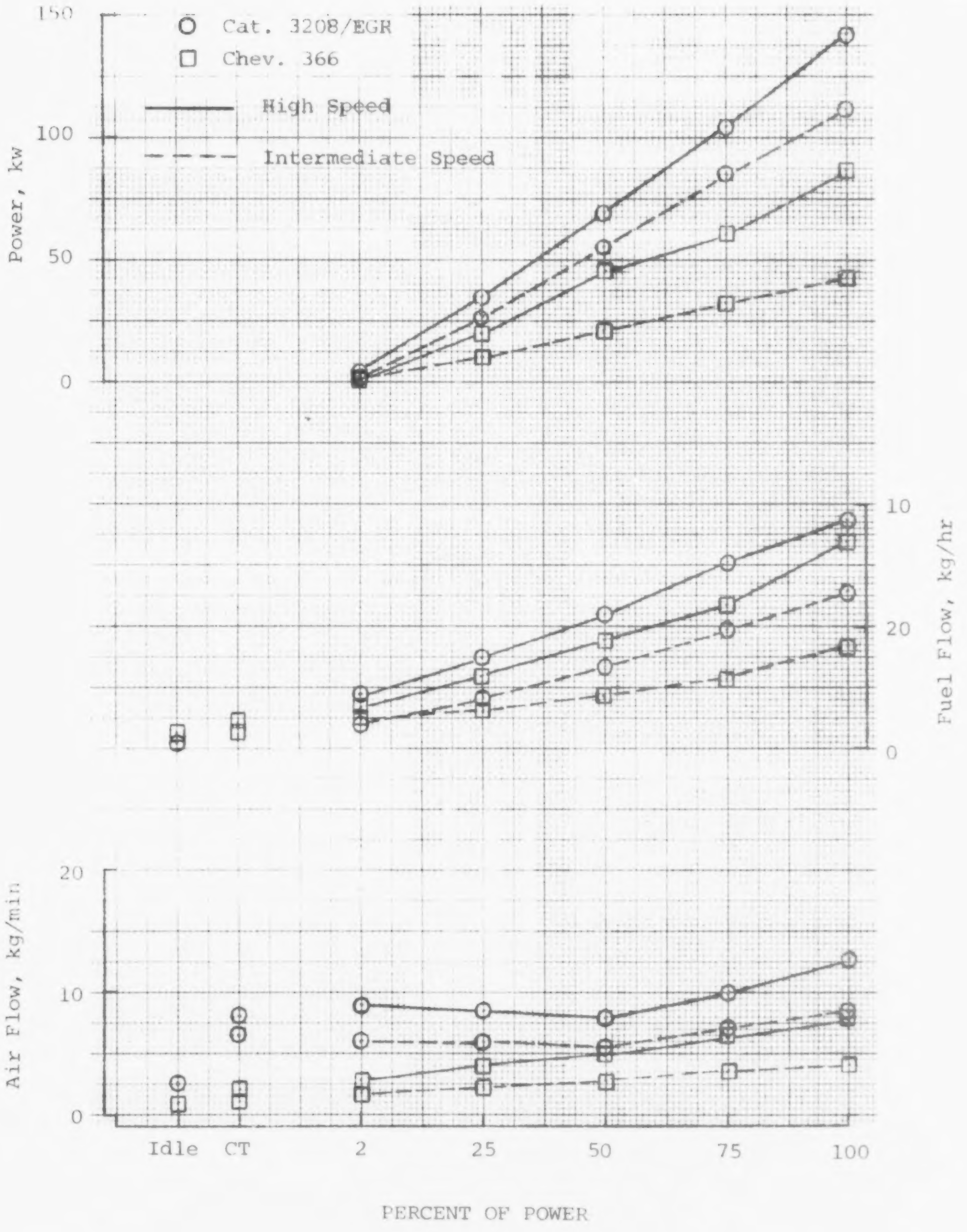

Figure 17. Power Output, Fuel and Air Rates from Caterpillar 3208 EGR and Chevrolet 366 Truck Engines

TABLE 17. BRAKE AND FUEL SPECIFIC CYCLE COMPOSITE PARTICULATE AND SULFATE RATES

			Particulate		Sulfate	
Engine	Cycle Wt.Fact.	Run No.	g/kw-hr	g/kg fuel	mg/kw-hr	mg/kg fuel
Mack ETAY(B)673A	13 FTP	1	0.845	3.628	47.047	202.03
		2	0.796	3.429	42.666	182.752
		Avg.	0.821	3.529	44.862	192.391
Cat 3208/EGR	13 FTP	1	2.96	10.17	22.19	76.21
		2	2.95	10.15	22.64	78.03
		Avg.	2.96	10.16	22.42	77.12
	EPA 23(1)	1	3.50	11.71	23.91	80.08
		2	3.46	11.65	24.81	83.53
		Avg.	3.48	11.68	24.36	81.81
Chev 366	13 FTP	1	0.260	0.583	1.377	3.085
		2	0.239	0.532	0.540	1.202
		Avg.	0.250	0.558	0.959	2.144
	EPA 23(1)	1	0.292	0.621	2.063	4.387
		2	0.261	0.554	0.705	1.494
		Avg.	0.277	0.588	1.384	2.941
	13 FTP	1			4.952(2)	11.094(2)
		2			5.720(2)	12.749(2)
		Avg.			5.336(2)	11.922(2)
	EPA 23(1)	1			5.922(2)	12.594(2)
		2			6.583(2)	13.959(2)
		Avg.			6.252(2)	13.277(2)
	13 FTP	2			6.279(3)	13.993(3)
	EPA 23	2			7.480(3)	15.860(3)

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(1) Weighting factors derived from EPA 23-mode test for use with 11 modes of 13-mode FTP and two cut-throttle modes.

(2) Reanalysis of IPA solutions nine weeks after initial analysis.

(3) Backup spare filter originally ammoniated, then placed into IPA solution and analyzed on 10/28/77.

particulate and sulfate results are computed on a brake specific (mass per kw-hr) and a fuel specific basis (mass per kg fuel consumed).

Listed below are the emission rates based on a 7-mode test (weighting factors derived from the 13-mode FTP) published in Reference 18.

	Particulate		Sulfate	
	g/kw-hr	g/kg fuel	mg/kw-hr	mg/kg fuel
Cummins 855 TC	0.381	1.44	35.02	131.89
DDAD 6V-71 LSN60	1.90	4.43	21.16	70.87
DDAD 8V-71 TA	0.697	2.45	48.37	170.06

The Mack ETAY(B)673A engine results may be compared to the Cummins 855TC, also a six-cylinder open chamber turbocharged Diesel engine. Particulate rates were more than double the 855TC engine while sulfate was only about 25 percent higher. This gross difference in particulate may be attributed to one or more differences in the fuel injection system or combustion systems, extent or turbocharging, etc. The fairly similar sulfate data indicates that fuel sulfur to sulfate conversion may be insensitive to such engine parameters.

The Caterpillar 3208 EGR engine particulate was some 3.6 times that of the Mack ETAY(B)673A engine and was substantially higher than the 2-stroke Detroit Diesel 6V-71 engine. The Caterpillar 3208 particulate is higher mainly because of the EGR system and is best compared to a similar Caterpillar 3208 but not EGR equipped. Such an engine was run under EPA Contract 68-02-1777 (Reference 35) and was found to produce 0.871 grams particulate/kw-hr and 28 mg sulfate/kw-hr using a self-compositing 13-mode cycle. This means the EGR equipped Caterpillar 3208 engine emitted over three times the brake specific particulate as the standard, non-EGR equipped 3208 model. Sulfate, on the other hand, was some 80 percent of the standard 3208 engine.

The next comparison of interest is the Caterpillar 3208 EGR and Chevrolet 366 engines. This is depicted on Figure 18, a bar chart of the average rates of Table 17. On a brake specific basis, the 3208 Diesel had some 12 times the 366 Chevrolet particulate rate. Based on fuel specific, the Caterpillar 3208 particulate rate was almost 18 times higher than the Chevrolet 366 engine. Recall that the Chevrolet cycle weighted brake specific fuel consumption is almost twice that of the Diesel and the reason for this can be understood. In other words, for the same particulate rate, the less fuel burned either modal or composite, the larger the fuel specific particulate value. If the fuel rate is higher, as it is with the gasoline versus the Diesel, the denominator is larger in the g/kg fuel expression, and thereby the differences between gasoline and Diesel engines can be explained.

For completeness sake, the Chevrolet 366 sulfate composites in Table 17 are based on the initial, very low results and the reanalyzed filters measured some nine weeks later. If the reanalyzed sulfate data are used for comparison, the Chevrolet 366 produced on the order of one-fourth the sulfate, on a mg/kw-hr basis, as the Caterpillar 3208 engine. This is shown on the lower half of Figure 18. Please recall that the gasoline engine was run with 0.03 percent by weight sulfur in the fuel while the Diesel engine operated on a fuel with 0.235 percent sulfur, an eightfold difference.

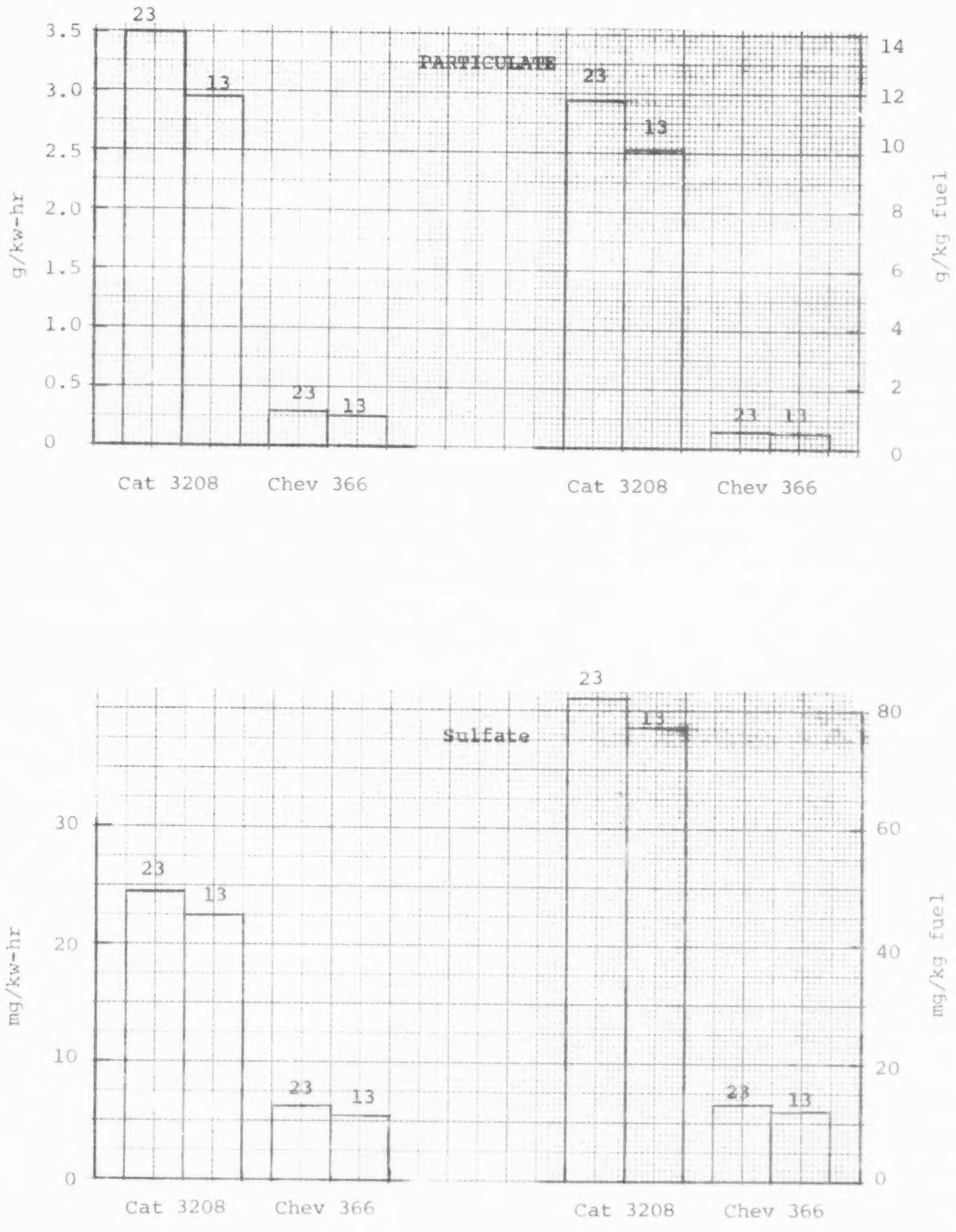

Figure 18. Comparison of Cycle Weighted Particulate and Sulfate Emission Rates - Caterpillar 3208 EGR and Chevrolet 366

In terms of mg of sulfate/kg fuel burned, the difference in sulfate is (based on 13- or 23-mode weighting factors) over six times from the Caterpillar than the Chevrolet 366. Again, the difference in brake specific fuel consumption, as with the previous particulate rate discussion, explains the greater difference in fuel specific versus brake specific rates of the two engines.

The composites summarized on Table 17 were from the measured grams of particulate and mg of sulfate per hour. Tables C-18 and C-19 are provided for the Mack engine, and Tables C-20 through C-23 are detailed listings for the Caterpillar 3208 EGR. Tables C-24 through C-27 list the alternative sets of sulfate data for the Chevrolet 366 as well as the particulate composites. It is interesting to note, from Figure 18, the similar cycle composite rates of particulate and sulfate for the Caterpillar 3208 EGR and Chevrolet 366 engines when using 13-mode FTP versus weighting factors derived from the 23-mode EPA test. The 23-mode EPA composites were consistently, though not substantially, higher than the 13-mode FTP composites.

D. Elemental and Metal Analyses

Table 18 is a listing of the percent by weight values for carbon, hydrogen and nitrogen. These elemental analyses were made using the 47 mm glass fiber filter dilution tunnel collected samples. These same filters were used to determine, by filter weight gain, the mass emissions of particulate per Table 14. The operating conditions were defined by Table 15. The two Diesels had very nearly the same carbon content at all loads except 75 percent at intermediate speed.

The percent carbon content of the Caterpillar 3208 EGR engine was higher at the high speed operation at all load conditions. Recall that the Caterpillar 3208 particulate rate was substantially higher and nonlinear, ostensibly due to the exhaust gas recirculation at the 2, 25, 50 and 75 percent power levels. Hydrogen content was higher for the Mack ETAY(B)673A engine. In those cases where carbon was lower, the hydrogen percentage will be higher.

The very low carbon content of the Chevrolet 366 gasoline engine is indicative of this type of engine. Relative to the two Diesels, the particulate is composed of materials other than represented by carbon, hydrogen and nitrogen. The combined C+H for the Caterpillar 3208 EGR ranged from 61 percent at idle to about 92 percent at 75 percent load, intermediate speed (1680 rpm) and 100 percent power, high speed (2800 rpm). For the Chevrolot 366, the C+H ranged from about 2.5 percent to 51.5 percent at intermediate speed (1200 rpm) and 100 percent load.

Aside from the mostly qualitative survey of the relative amounts of carbon, hydrogen and nitrogen, the "percent by weight" values may be used directly with the particulate rates already discussed. For example, the mass emission rates for particulate on Table 14 may be multiplied by the decimal equivalent of the appropriate Table 18 percent carbon to obtain an estimation of the mass emission rate of particulate as carbon.

Table 19 lists the results of the metals analysis performed through the cooperation of the EPA-Research Triangle Park Laboratories. The EPA-RTP X-ray fluorescence metals analysis equipment has been found to be superior in both the number of metals and analytical precision to laboratories available to SwRI for this analysis. The analysis was made from particulate collected

TABLE 18. ELEMENTAL ANALYSIS OF FILTER COLLECTED PARTICULATE

(Percent by Weight based on 47 mm Fiberglass Filter Samples)

Condition Speed/% Load	Element	Mack ETAY(B)673A	Cat 3208/EGR	Chev 366
Inter/02	Carbon	58.50	66.46	1.94
	Hydrogen	9.12	7.36	1.92
	Nitrogen	1.16	0.76	<0.1
Inter/25	Carbon	70.40	70.04	2.00
	Hydrogen	4.79	5.80	0.77
	Nitrogen	1.62	0.56	<0.1
Inter/50	Carbon	81.03	80.31	0.27
	Hydrogen	2.97	2.76	2.46
	Nitrogen	0.94	0.30	<0.1
Inter/75	Carbon	78.54	89.82	4.39
	Hydrogen	2.06	1.75	0.92
	Nitrogen	0.82	0.24	0.93
Inter/100	Carbon	88.09	87.74	47.18
	Hydrogen	2.15	1.15	4.36
	Nitrogen	0.78	0.28	<0.1
Idle	Carbon	62.23	55.80	5.66
	Hydrogen	7.45	5.33	0.45
	Nitrogen	0.96	0.91	<0.1
Inter/CT	Carbon	(1)	75.90	15.63
	Hydrogen	(1)	9.73	3.54
	Nitrogen	(1)	0.09	<0.1
High/100	Carbon	67.33	90.47	1.46
	Hydrogen	2.43	1.28	1.07
	Nitrogen	1.04	0.45	0.44
High/75	Carbon	77.41	88.59	24.90
	Hydrogen	3.22	1.09	1.63
	Nitrogen	0.96	0.36	0.25
High/50	Carbon	68.67	82.27	1.12
	Hydrogen	3.21	1.45	0.21
	Nitrogen	1.24	0.21	<0.1
High/25	Carbon	69.18	82.51	<0.1
	Hydrogen	5.55	3.24	2.06
	Nitrogen	1.14	0.47	<0.1
High/02	Carbon	58.78	77.18	<0.1
	Hydrogen	8.26	6.83	2.41
	Nitrogen	0.36	0.55	<0.1
High/CT	Carbon	(1)	78.35	19.86
	Hydrogen	(1)	10.17	3.67
	Nitrogen	(1)	0.19	<0.1

(1) Condition not run

TABLE 19. METALS ANALYSIS OF FILTER COLLECTED PARTICULATE
(Percent by Weight Based on Fluoropore Filter Samples)

Cond. Speed/ % Load	Engine[1]	Cr	Pb	Mn	Br	P	Si	Cd	Al	S	Na	Mg	K	Cl	Zn	Cu	Ni	Fe	Ba	Ca
(Detection Limits) µg/filter		1.37	3.05	2.42	2.69	0.13	0.05	0.03	0.03	0.20	0.53	0.04	0.06	0.21	0.50	2.05	0.32	1.49	0.18	0.19
Inter/ 02	Mack		0.76			0.40	0.1		0.1	2.9		0.03	0.04	0.09			0.09			0.2
	Cat					0.01	0.02	0.02		1.0			0.009		0.08					0.1
	Chev		68.4		31.8	0.20	0.09	0.2	0.41	0.35		0.03	0.01	11.7	0.09		0.09			0.1
Inter/ 25	Mack		0.63	0.39		0.03				4.60		0.005	0.01		0.03					0.04
	Cat					0.01	0.01	0.007		1.64			0.004		0.07					0.08
	Chev		89.0		47.4	0.20	0.2	0.2	0.66	0.2		0.05	0.03	17.0	0.1				0.05	0.03
Inter/ 50	Mack		0.13			0.02				2.62		0.003					0.02			0.02
	Cat					0.03		0.002		1.29			0.003	0.02	0.04		0.01			0.03
	Chev		71.4		42.8	0.02	0.04	0.02	0.59			0.04	12.1							0.08
Inter/ 75	Mack		0.18	0.11		0.01	0.004		0.02	3.12		0.004	0.004	0.04	0.02					0.03
	Cat		0.06	0.05		0.02	0.001	0.001		0.67			0.001	0.03	0.04					0.03
	Chev	0.72	67.1		42.9	0.03	0.01	0.01	0.49			0.04		8.02	0.05	0.30	0.05			0.03
Inter/ 100	Mack		0.11	0.08		0.02	0.003			2.21		0.004	0.002	0.51	0.04			0.04		0.05
	Cat		0.04	0.03		0.01	0.002	0.002		0.60			0.002	0.05	0.03					0.03
	Chev		24.8		10.7		0.02	0.06	0.19			0.02	0.004	6.66						0.06
Idle	Mack					0.03				2.3			0.01							0.06
	Cat						0.03	0.006		2.33			0.006							0.01
	Chev	1.8	58.5		18.2	0.2	0.03	0.1	0.3			0.03	0.006	12.6						0.03
Inter/ CT	Mack	Condition not run																		
	Cat					0.05	0.005	0.003		0.34			0.005	0.04	0.02					0.05
	Chev		45.5		11.6	0.27	0.02	0.01	0.01	0.50	0.27	0.02		8.88						0.07
High/ 100	Mack		0.16			0.13			0.003	5.06		0.01	0.005	0.04	0.27			0.11		0.28
	Cat					0.12	0.007	0.005	0.002	0.92			0.002	0.11	0.23			0.04	0.01	0.29
	Chev	0.96	50.4		28.2	0.01	0.02	0.11	0.19			0.04		9.88	0.02	0.18		0.10		0.05
High/ 75	Mack		0.28			0.06				5.16			0.002		0.1					0.13
	Cat			0.03		0.02	0.002	0.002		0.41			0.001	0.05	0.5					0.04
	Chev		55.3		25.8		0.02	0.1	0.26			0.05		11.0		0.34				0.03
High/ 50	Mack					0.06				5.64			0.006	0.03	0.05					0.06
	Cat		0.05			0.01	0.003	0.003		0.63			0.003	0.02	0.02					0.03
	Chev		57.2		29.9		0.01	0.01	0.26			0.03		8.99						
High/ 25	Mack		0.43	0.25		0.04	0.004			3.90		0.006	0.004		0.09					0.04
	Cat		0.04	0.03		0.01	0.001	0.01		0.88			0.001	0.01	0.03		0.01			0.02
	Chev		78.4		42.0	0.06	0.06	0.2	0.56		0.2	0.03		10.0	0.06	0.47	0.09			0.06
High/ 02	Mack		0.46	0.32		0.02				2.08			0.009		0.05		0.05		0.02	0.05
	Cat					0.02	0.004	0.004		0.83			0.004	0.03	0.05					0.07
	Chev		58.2		18.4	0.50	0.01	0.1	0.2			0.03	0.004	6.32						0.10
High/ CT	Mack	Condition not run																		
	Cat					0.06		0.006		0.31			0.01		0.07					0.07
	Chev		47.5		10.1	0.54	0.02	0.08	0.08			0.04		4.46	0.10					0.20

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[1] Mack ETAY(B)673A, Caterpillar 3208 EGR, Chevrolet 366

on the duplicate Fluoropore filter taken at the same time as the Fluoropore filter for sulfate analysis.

Only calcium was found in all samples from all engines. Phosphorus and silica were the next most popular elements in the particulate. Sodium, iron, nickel, barium, chromium and copper were seldom found and at low levels. The two Diesels were not consistent in either the specific metal or its level. Sometimes the Caterpillar 3208 had less and sometimes more of a specific element.

Comparing the Caterpillar 3208 EGR and Chevrolet 366, major differences are noted. First, it is evident that the particulate from the gasoline engine is that of tetraethyl lead motor mix combustion products. These are indicated mainly by the lead percentages and to a lesser degree by the bromine and chlorine values, the lead scavengers. One way of comparing the two engines is to sum the various percentages on Table 19. The Caterpillar Diesel had an average of 1.1 percent of the particulate reqresented by the elemental analysis, not counting carbon, hydrogen and nitrogen, while the Chevrolet 366 averaged 98 percent. The lead plus chlorine plus bromine average percentage was 96 percent, with about 2 percent of the particulate attributed to the other metals and elements analyzed as listed on Table 19.

Another item of interest is the lower sulfur content of the Chevrolet 366 relative to the Caterpillar 3208. Only in two conditions was sulfur reported for the Chevrolet 366 (in other modes the sulfur was apparently below the minimum detectable), and the Chevrolet 366 was about 20 percent of the sulfur from the Caterpillar 3208. A final comment relates to the several Chevrolet 366 test conditions in which the combined lead, bromine and chlorine is greater than 100 percent. This is apparent during all four power conditions at intermediate speed of 1200 rpm and during the high speed 25 percent mode. The specific reason for this is unknown, although it may have to do with the specific location on the filter where the X-ray was taken. It is speculated that maybe the lead and lead scavenger products may not distribute over the 47 mm Fluoropore filter uniformly and thereby could result in their overstatement when ratioed to the entire filter. The answer to this is not readily available and the reader should be cautioned when using Table 19 data in this way.

E. Benzo(a)Pyrene Analyses

The results of the analysis of BaP, the polynuclear aromatic hydrocarbon measured, are listed on Table 20. These analyses were based on the samples collected by larger, 203 by 254 mm (8 x 10 inch) fiberglass filters during a separate set of tests. Usually, the large filters were taken as soon as the 47 mm size filter runs were completed. Table 21 is a summary of pertinent engine operating conditions observed during collection of the 8 x 10 samples for BaP. The conditions are quite similar to those listed on Table 15 for the 47 mm filters.

The BaP analysis of the Mack ETAY(B)673A engine was performed by Southwest Foundation for Research and Education. The Caterpillar 3208 and Chevrolet 366 engine samples were extracted and analyzed through the cooperation of Dr. Robert H. Jungers of the Environmental Monitoring and Support Laboratory, EPA, Research Triangle Park, North Carolina. The repeated difficulties in

TABLE 20. SUMMARY OF PARTICULATE, BaP AND ORGANIC SOLUBLES
FROM 8 X 10 SIZE GLASS FILTER SAMPLES

Condition Speed/Load, %	Engine(1)	Particulate Rate $\frac{mg}{m^3}$	$\frac{g}{hr}$	$\frac{g}{kg\ fuel}$	$\frac{g}{kw\text{-}hr}$	BaP Rate $\frac{\mu g}{m^3}$	$\frac{\mu g}{hr}$	$\frac{\mu g}{kg\ fuel}$	$\frac{\mu g}{kw\text{-}hr}$	Organi Solub. % (4
Inter/02	Mack	27.10	12.26	2.76	2.61	0.557	252.0	56.0	54.0	34.84
	Cat	86.30	26.53	6.631	12.631	0.147	45.1	11.3	21.5	16.98
	Chev	13.90	1.17	0.266	1.300	Below Minimum Detectable				2.40
Inter/50	Mack	112.61	81.36	3.25	0.71	0.647	481.0	18.0	4.0	9.3
	Cat	188.16	53.70	3.920	0.945	0.116	33.1	2.4	0.6	6.66
	Chev	13.22	1.79	0.217	0.088	0.0093	1.3	0.2	0.1	3.99
Inter/100	Mack	182.04	189.95	3.87	0.81	0.162	166.0	3.0	1.0	3.5
	Cat	429.25	190.27	7.446	1.675	Below Minimum Detectable				2.72
	Chev	52.52	10.71	0.634	0.255	1.9138	390.2	23.2	9.3	2.0
Idle	Mack	17.88	3.23	2.28	(2)	0.441	80.0	62.0	(2)	15.54
	Cat	41.45	4.88	5.417	(2)	0.210	23.9	27.0	(2)	8.19
	Chev	14.95	0.72	0.289	(2)	Below Minimum Detectable				6.05
Inter/CT	Mack	Condition not run								
	Cat	91.17	17.90	(3)	(2)	0.119	31.9	(3)	(2)	23.3
	Chev	18.17	1.10	0.393	(2)	0.0117	0.7	0.3	(2)	5.6
High/100	Mack	127.13	180.23	3.19	0.72	0.162	229.0	4.0	1.0	1.0
	Cat	340.67	230.02	6.077	1.585	Below Minimum Detectable				2.7
	Chev	64.99	26.69	0.789	0.303	2.045	289.9	40.3	170.5	3.90
High/50	Mack	73.19	71.33	2.42	0.57	0.526	514.0	17.0	4.0	6.3
	Cat	905.35	380.16	16.727	5.507	1.668	700.2	30.8	10.1	2.18
	Chev	22.66	5.80	0.331	0.133	0.1082	27.7	1.6	0.6	2.6
High/02	Mack	27.75	16.95	2.20	2.91	0.494	303.0	40.0	58.0	38.46
	Cat	116.92	53.47	5.875	15.276	0.193	88.1	9.7	25.2	9.3
	Chev	20.39	2.89	0.402	1.700	0.0159	6.5	0.2	0.1	1.7
High/CT	Mack	Condition not run								
	Cat	72.14	33.83	(3)	(2)	0.108	49.6	(3)	(2)	23.6
	Chev	30.25	3.35	0.769	(2)	0.0292	3.2	0.7	(2)	2.8

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(1) Mack ETAY(B)673A, Caterpillar 3208 EGR, Chevrolet 366.

(2) Brake specific not calculated since idle and CT produce no power output.

(3) No fuel consumption measurable.

(4) Determined as organic solubles in benzene, Chevrolet 366 by RTP and Caterpillar 3208 by RTP/SwRI.

TABLE 21. SUMMARY OF ENGINE OPERATING CONDITIONS DURING 8 x 10 SIZE GLASS FILTER TESTS

Condition Speed/Load %	Engine(1)	Engine Speed rpm	Power Output kw,obs	Fuel Rate kg/hr	Air Rate kg/min	BSFC kg/kw-hr	Inlet Air °C	Inlet Rest. mm Hg	Exh. Rest. mm Hg
Inter/02	Mack	1450	4.7	4.4	8.99	0.936	24	9.90	25.40
	Cat	1680	2.1	4.0	6.08	1.905	29	13.08	3.81
	Chev	1200	0.9	4.4	1.68	4.889	38	32.46	3.81
Inter/50	Mack	1450	115.7	24.9	13.26	0.215	25	17.28	29.21
	Cat	1680	56.8	13.7	5.49	0.241	31	11.25	3.81
	Chev	1200	20.4	8.2	2.7	0.402	44	18.66	5.33
Inter/100	Mack	1450	236.0	49.3	20.07	0.209	25	33.35	44.45
	Cat	1680	113.6	25.6	8.46	0.225	29	22.32	17.78
	Chev	1200	42.1	16.9	4.08	0.401	42	0.58	14.86
Idle	Mack		0	1.5	3.66	-----	24	2.81	26.67
	Cat		0	0.9	2.33	-----	29	2.99	0
	Chev		0	2.5	0.96	-----	37	30.82	0.76
Inter/CT	Mack	Condition not run							
	Cat	1680	0	0	5.37	-----	23	10.47	25.4
	Chev	1200	0	2.8	1.21	-----	33	39.06	0.70
High/100	Mack	1900	251.1	56.5	26.91	0.225	23	46.7	63.5
	Cat	2800	152.2	37.9	12.93	0.249	27	47.36	62.3
	Chev	2300	87.9	33.7	8.21	0.383	38	1.15	61.0
High/50	Mack	1900	125.4	29.5	18.79	0.235	25	27.56	44.45
	Cat	2800	69.6	22.8	8.02	0.328	26	20.46	20.32
	Chev	2300	43.7	17.6	5.12	0.403	44	19.38	24.13
High/02	Mack	1900	5.9	7.7	12.13	1.305	24	14.01	25.40
	Cat	2800	3.5	9.1	9.01	2.600	29	24.47	12.70
	Chev	2300	1.7	7.3	2.83	4.294	39	35.59	4.70
High/CT	Mack	Condition not run							
	Cat	2800	0	0	9.27	-----	28	25.97	11.43
	Chev	2300	0	4.4	2.21	-----	39	41.05	0.96

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(1) Mack ETAY(B)673A, Caterpillar 3208 EGR, Chevrolet 366

BaP measurement experienced not only by SFRE but others prompted the decision to send all such filters for BaP analysis to EPA-RTP. Dr. Jungers of EPA's Analytical Chemistry Laboratory (EMSL) routinely performs BaP analysis of similar 8 x 10 filters used in Hi-Vol atmospheric sampling. Accordingly, this method was authorized by EPA for BaP analysis of engine collected samples until a test procedure specific for several of the PNA's can be developed.

There is a difference between the BaP from the two Diesels (based on concentration, brake and fuel specific) which may be due to the engine or the method of analyses. One exception was the high speed, 50 percent power condition. In this case, the Caterpillar 3208 engine had much higher BaP than the Mack engine. In other power conditions, the Mack engine had higher BaP. Some of the difference may be attributed to the extraction-analysis procedure in use at SFRE as it was thought to give "higher" results. But the reversal at the 50 percent high speed point may be coincident with the massive amount of particulate at that point due to the EGR rate. The higher BaP might be due to the air-fuel ratio change that occurred with EGR.

An even greater difference is seen between the BaP from the Chevrolet 366 and Caterpillar 3208 engines. In this case, the extractions and analyses were performed by the same laboratory and may be directly compared. Except for the two modes, the high-power intermediate-speed and the high-speed 2-percent-power, the BaP from the Chevrolet 366 can be considered negligible and approaching that or below the minimum detectable limit of Dr. Jungers' instrument. This is not surprising in light of results under Phase II (discussed in Section VI) of this project for the Diesel counterparts of production gasoline cars. The two modes mentioned had substantially higher BaP rates, almost as if each condition was a purge of stored BaP.

Table 22 summarizes the cycle weighted composite BaP rates for this test series. All engines were cycle composited on a 7-mode basis using weighting factors derived from the 13-mode FTP and 23-mode EPA cycles. The Caterpillar and Chevrolet engines also ran the two cut throttle modes of the 23-mode EPA procedure. Thus, additional cycle composite 9-modes were computed using weighting factors derived from the 23-mode test factors. As shown in Figure 19, the composites indicate the difference between the gasoline and Diesel engine under HD test conditions were small. The two high BaP modes of the Chevrolet 366 apparently brought the composites up to the Caterpillar 3208 rates. In

TABLE 22. COMPOSITE BaP RATES

	Brake Specific, μg/kw-hr			Fuel Specific, μg/kg Fuel		
	7-Mode(1)	7-Mode(2)	9-Mode(2)	7-Mode(1)	7-Mode(2)	9-Mode(2)
Mack ETAY(B)673A	2.917	3.053	-----	12.395	12.571	-----
Cat 3208/EGR	2.658	2.314	2.494	9.591	7.648	8.483
Chevrolet 366	3.330	3.018	3.033	7.838	7.327	6.864

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(1) Based on weighting factors derived from 13-mode FTP.
(2) Based on weighting factors derived from 23-mode EPA.

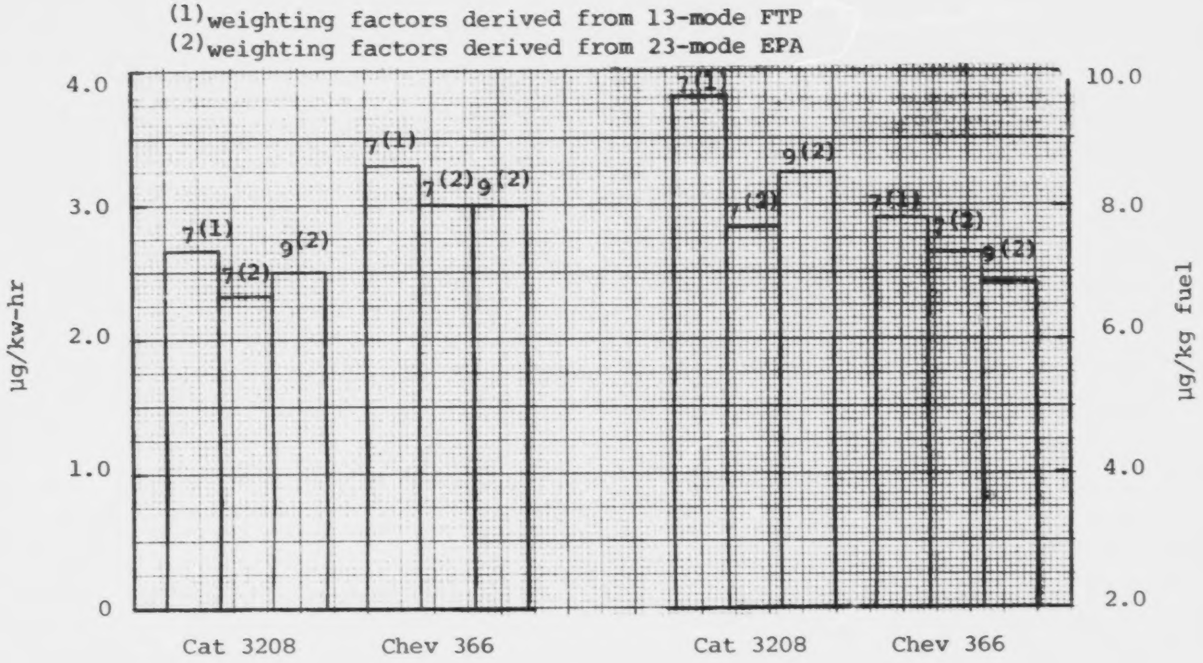

Figure 19. Cycle Composite BaP Comparison
Caterpillar 3208 EGR and Chevrolet 366

terms of brake specific BaP, the Chevrolet 366 was higher regardless of cycle. In terms of fuel specific, μg of BaP per kg fuel, the Chevrolet 366 was lower than the Caterpillar 3208 EGR. The reason for this reversal is the gross difference in brake specific fuel consumption for the two engines. The 7-mode derived from the 13-mode FTP always gave the highest rates.

This was the first time such measurements have been attempted with a gasoline HD engine running on a leaded regular grade gasoline (1.6 g/gal lead and 91.5 RON). The engine did not have an oxidation catalyst in the exhaust. Because the particulate levels were so low on the 8 x 10 size filters, duplicate filters were obtained and Dr. Jungers advised to use both whole filters in his analysis. Thus the extracts and BaP content as well as the benzene organic extract, as a percent of the particulate weight, are based on the combination extract of two separately obtained filters for each of the nine conditions run. The absolute levels of BaP from the Chevrolet 366 engine are far from verified at this time. More work should be done with other leaded fueled gasoline engines to obtain insight into the BaP behavior and try to understand why the BaP was apparently so high during the 100 percent, WOT, power modes with the Chevrolet 366 engine. Was power valve fuel enrichment at these modes the reason? Or, was there a purge-out of BaP matter from the exhaust system?

Extracts for the Caterpillar 3208 EGR were returned by Dr. Jungers and were dried and weighed, and the organic extract fraction was determined by SwRI. It is interesting to compare the percent benzene organic extract of the Chevrolet 366 to HDD engines in general and a Caterpillar 3208 engine run on a project for Dr. Bradow. The Chevrolet 366 results ranged from 2 to 6 percent while Diesels (4-stroke cycle) run from 5 to 20 percent and the Caterpillar 3208 (not EGR) ranged from 12 to 18 percent.

The particulate content of the gasoline HD engine is expected to contain, by weight, products of combustion of the TEL along with some C, H and N and trace metals. Sulfate, as with the Diesel engine, is considered at a minor level since only 0.4 to 2.3 percent of the fuel sulfur (0.03 percent by weight) was converted to that which was measured as sulfate by the BCA procedure.

Please refer to Tables C-28 through C-30 for run-by-run BaP and 8 x 10 particulate data and organic solubles. Tables C-31 through C-37 list the computations for 7- and 9-mode cycle composites.

F. Odor and Related Instrumental Analyses

The Diesel engine exhaust odor mapping and related instrumental analyses resulted in a substantial amount of data. As explained earlier, odor tests were not made of the Chevrolet 366 gasoline engine.

1. Odor Ratings by Trained Panel

Table 23 summarizes the average odor ratings and Table 24 lists pertinent engine data for the two engines tested. Each engine model is discussed separately.

TABLE 23. AVERAGE ODOR PANEL RATINGS, 100:1 DILUTION

Condition Speed/Load %	Engine[1]	"D" Composite	"B" Burnt	"O" Oily	"A" Aromatic	"P" Pungent
Inter/02	Mack	2.9	1.0	0.9	0.8	0.5
	Cat	3.1	1.1	0.9	0.6	0.4
Inter/50	Mack	2.6	1.0	0.9	0.7	0.4
	Cat	3.6	1.2	0.9	0.7	0.5
Inter/100	Mack	3.2	1.0	1.0	1.0	0.7
	Cat	3.2	1.1	1.0	0.6	0.4
High/02	Mack	3.2	1.0	1.0	0.9	0.6
	Cat	4.6	1.6	1.1	0.8	0.9
High/50	Mack	2.9	1.0	1.0	0.9	0.5
	Cat	4.2	1.4	1.0	0.8	0.8
High/100	Mack	3.3	1.1	1.0	0.8	0.8
	Cat	3.5	1.1	0.9	0.7	0.6
Idle	Mack	3.5	1.0	1.0	1.0	0.8
	Cat	3.5	1.2	0.9	0.7	0.6
Idle-Accel	Mack	3.1	1.0	1.0	0.7	0.7
	Cat	3.5	1.2	1.0	0.7	0.7
Accel	Mack	3.2	1.0	1.0	0.8	0.7
	Cat	3.7	1.2	1.0	0.7	0.8
Decel	Mack	2.7	1.0	1.0	0.6	0.5
	Cat	3.3	1.1	0.9	0.7	0.5
Cold Start	Mack	4.4	1.5	1.0	1.0	1.0
	Cat	4.1	1.4	1.0	0.7	0.7

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(1) Mack ETAY(B)673A, Caterpillar 3208 EGR

TABLE 24. AVERAGE ENGINE OPERATING DATA TAKEN SIMULTANEOUSLY WITH ODOR RATINGS

Condition Speed/Load,%	Engine(1)	Engine Speed rpm	Power Output kw,obs	Fuel Rate kg/hr	Air Rate kg/min	BSFC kg/kg-hr	Inlet Air °C	Exh. Temp °C	Inlet Rest. mm Hg	Exh. Rest. mm Hg
Inter/02	Mack	1450	4.50	5.40	9.09	1.20	29	171	7.85	2.54
	Cat	1680	2.09	5.00	5.86	2.39	30	263	12.14	7.62
Inter/50	Mack	1450	113.4	24.54	12.73	0.216	31	437	14.57	5.08
	Cat	1680	58.46	14.42	5.37	0.247	29	450	11.02	7.62
Inter/100	Mack	1450	226.7	49.99	19.82	0.221	29	527	32.32	15.24
	Cat	1680	116.93	25.67	8.40	0.220	29	653	22.79	22.86
High/02	Mack	1900	4.90	8.94	12.06	1.824	30	246	13.08	3.81
	Cat	2800	2.78	12.56	8.61	4.518	30	404	23.16	20.32
High/50	Mack	1900	122.0	30.03	18.60	0.246	29	396	26.34	10.16
	Cat	2800	75.17	24.45	7.72	0.325	31	652	20.73	27.94
High/100	Mack	1900	244.0	57.11	25.55	0.234	30	529	46.70	22.86
	Cat	2800	150.33	82.90	12.76	0.551	29	733	47.1	63.50
Idle	Mack	630	(2)	1.91	3.67	(3)	29	145	1.68	1.27
	Cat	600	(2)	1.04	2.02	(3)	31	174	2.43	2.03

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(1) Mack ETAY(B)673A, Caterpillar 3208 EGR.
(2) No power observed.
(3) Not calculated since no power output.

a. Mack ETAY(B)673A

Figure 20 illustrates the "D" Diesel intensity as a function of the six steady-state loads and speed conditions. Little effect is noticed with average "D" odor intensities in the range of "D"-3±0.3. The bar chart on the bottom half of Figure 20 compares the total "D" + "B" + "O" + "A" + "P" ratings for the same six steady-states, the idle, idle-accel, accel, decel and cold start conditions. It is interesting to note that odor levels measured during transients are about the same as during steady-states and that the cold start was the highest combined level observed. Tables C-38 through C-40 list the detailed test and replicate odor data on which the summary trends are based.

b. Caterpillar 3208 EGR

Figure 21 shows the relationship of the observed odor intensity "D" value versus power for both speeds. As with the Mack engine (see Figure 20), a lack of effect is noted for the six steady states with "D" nominally 3±0.4 units. This odor level is noticeable and would be considered objectionable to most. The lower part of Figure 21 shows that the 2 and 50 percent power at 2800 rpm modes resulted in the highest combined odor perceived. The three transients were within the range of the six steady-states. The cold start odor ranked third from the highest for this engine. The high odor ranking at 2 to 50 percent load, 2800 rpm, was due to the higher quality ratings for B, O, A and P relative to other modes. The "D" or overall intensity, as mentioned earlier, was essentially a constant or flat response for all loads and speeds. For additional run-to-run (odor panel rating) detail, please refer to Tables C-41 through C-43.

2. Supplemental Gaseous Emissions

Table 25 lists the supplemental gaseous emissions taken at the same time as the steady-state runs. NO was measured by both NDIR and CL while NO_x ($NO+NO_2$) was measured by CL. The NO_2 portion of the exhaust, difference between NO_x and NO by CL, was about 25 ppm (12-49 ppm range) for the Mack ETAY(B)673A engine. NO_2 for the Caterpillar 3208 EGR engine was about 9 ppm average with a range of 4 to 19 ppm. Evidently, the Caterpillar 3208 produces less NO_2 than the Mack engine as tested, even though at maximum power, where no EGR is scheduled, the Caterpillar and Mack engines have fairly similar NO_x levels. The differences in HC and CO between the two engines are consistent with the 13-mode FTP data obtained earlier. In the case of the Mack engine, the odor tests were run at an engine backpressure setting that was not artificially increased. The Caterpillar 3208 engine was run with the backpressure and inlet restrictions set per the 13-mode FTP.

Appendix Tables C-45 through C-47 are tabulations of the modal run-by-run gaseous emissions taken during the six steady state and idle odor tests. Transient data were not obtained due to the very great technical difficulty associated with raw exhaust analysis during very rapid accelerations and decelerations. Tables C-48 through C-51 are similar data listings but for the Caterpillar 3208 engine.

3. Odor by DOAS

The Diesel Odor Analytical System was also used to determine concentrations of odorant compounds. The results of these measurements are

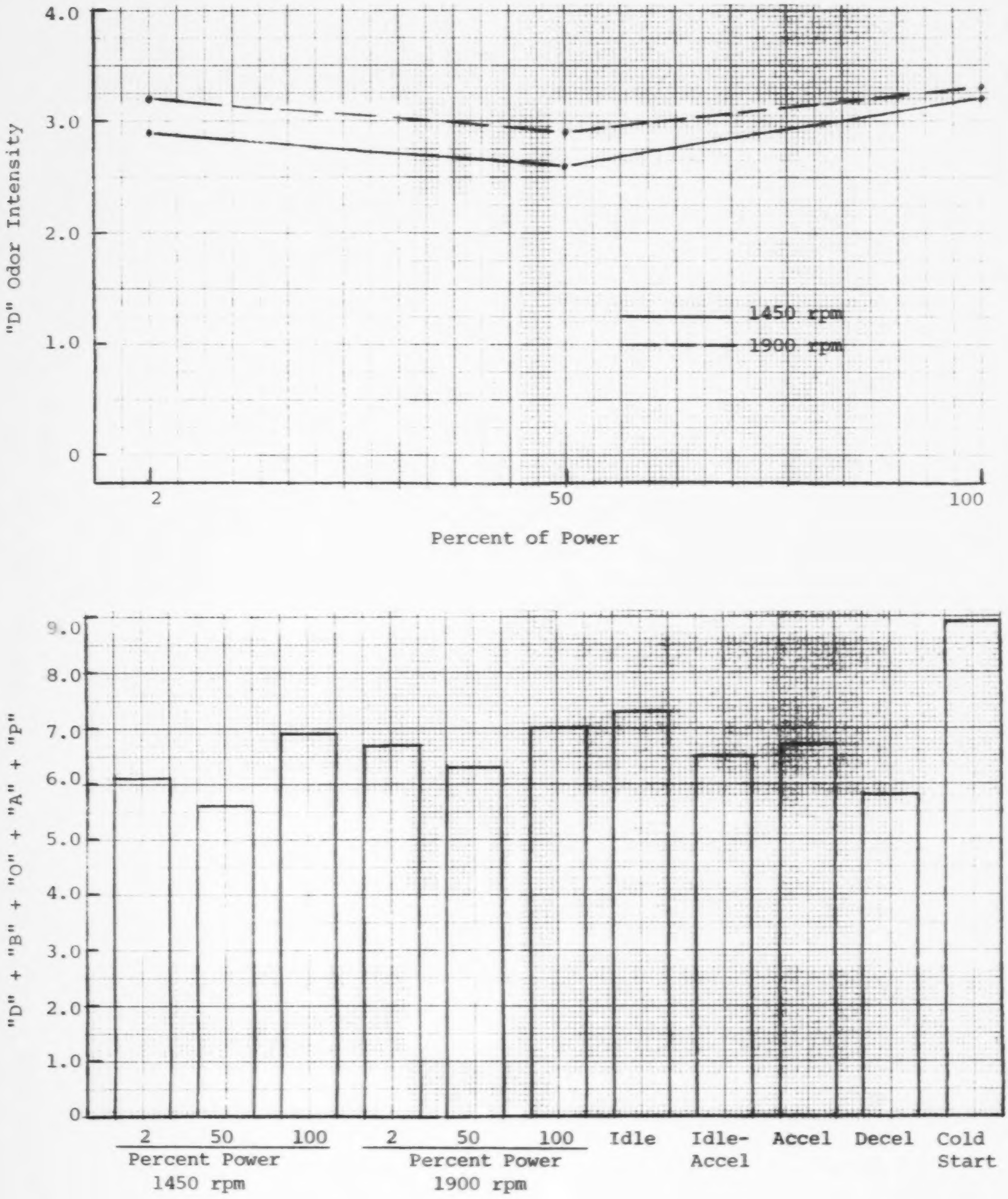
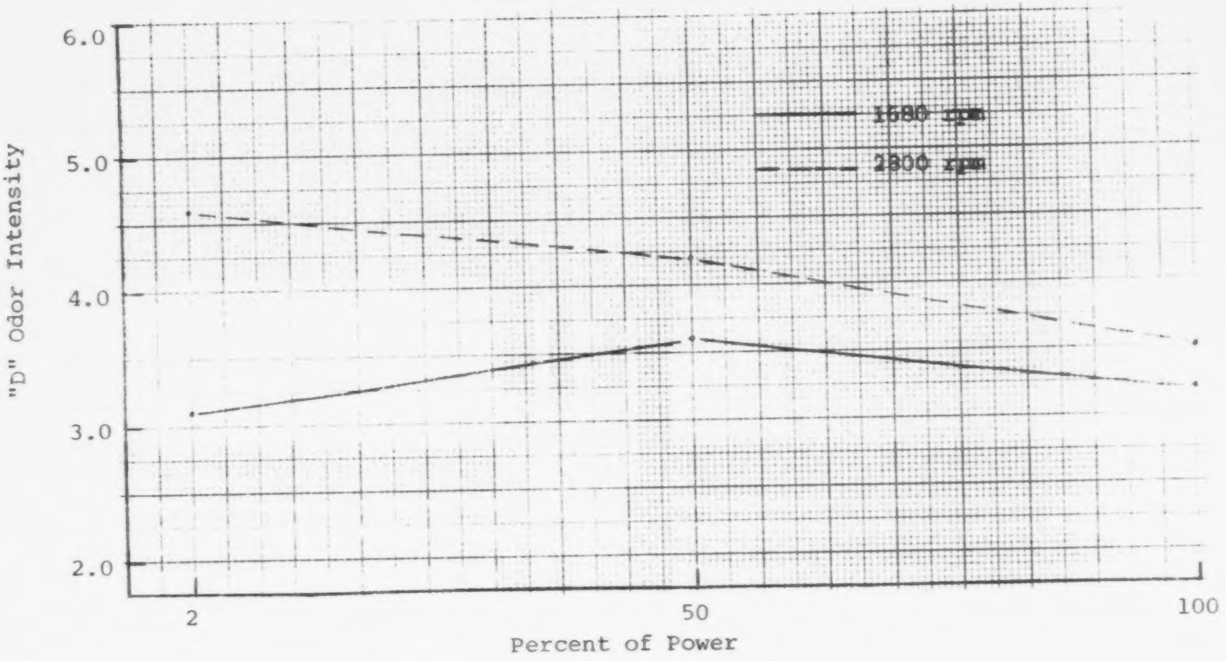


Figure 20. Mack ETAY(B)673A Engine Diesel Odor Intensity by Trained Panel



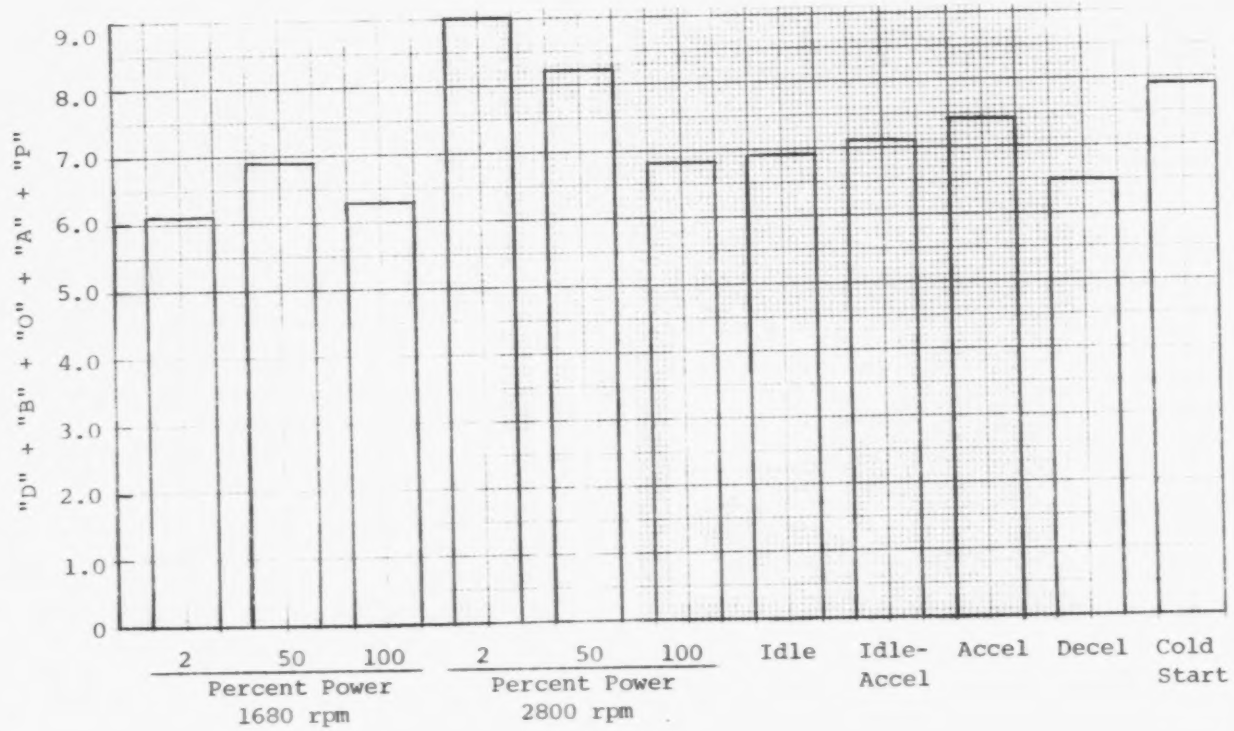


Figure 21. Caterpillar 3208 EGR Engine
Diesel Odor Intensity by Trained Panel

TABLE 25. AVERAGE EXHAUST ANALYSES TAKEN SIMULTANEOUSLY WITH ODOR RATINGS

Operating Condition	Engine[1]	HC ppm	CO ppm	CO_2 %	NDIR NO ppm	NO ppm	NO_x ppm	LCA µg/l	LCO µg/l	TIA
Inter Speed 2% Load	Mack	222	226	2.1	213	170	206	14.5	7.0	1.9
	Cat	397	434	3.1	171	158	169	46.3	21.7	2.3
Inter Speed 50% Load	Mack	126	200	7.0	922	843	865	10.8	5.1	1.7
	Cat	378	556	10.4	253	251	256	58.7	24.1	2.4
Inter Speed 100% Load	Mack	61	373	9.0	1204	1075	1090	6.8	5.0	1.7
	Cat	107	1231	11.7	1254	1184	1203	25.8	18.2	2.3
High Speed 2% Load	Mack	268	226	2.5	155	129	154	17.4	6.5	1.8
	Cat	554	873	5.6	157	151	155	60.0	36.0	2.6
High Speed 50% Load	Mack	155	139	5.9	551	471	488	15.6	6.8	1.9
	Cat	455	4066	11.9	189	181	186	42.1	32.0	2.5
High Speed 100% Load	Mack	41	294	8.7	919	819	831	5.8	4.3	1.7
	Cat	30	1169	11.9	718	691	698	25.3	15.1	2.2
Idle	Mack	221	231	1.4	247	199	248	11.5	5.9	1.8
	Cat	358	359	2.2	184	169	190	26.8	13.9	2.2

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[1] Mack ETAY(B)673A, Caterpillar 3208 EGR

summarized on Table 25 in μg/ℓ of LCA and LCO. The LCO value is computed in TIA units by the expression

$$TIA = 1 + \log_{10} LCO$$

The individual DOAS results for both engines are listed on Tables C-45 through C-47 (Mack) and C-48 through C-51 (Caterpillar).

Recall that chemical traps are used to obtain the samples of exhaust for analysis. Thus, only the steady-state engine conditions were sampled. Figure 21a is a plot of the TIA versus "D" rating by trained panel for the Mack ETAY(B)673A and Caterpillar 3208 EGR engines. It is interesting to note that the average TIA for the Caterpillar was like the overall panel average, higher than for the Mack engine "D" rating. This is summarized in the following comparison based on the average six steady-state plus idle runs.

	Mack ETAY	Cat 3208
"D" by Panel	3.1	3.7
TIA by DOAS	1.78	2.37

It is difficult to say that the TIA and "D" ratings really correlate, although the agreement seems better than previously reported data for other heavy-duty engines.

In addition to the determination of the DOAS values for both engines, a series of correlation experiments was performed in conjunction with Dr. Joe Perez of Caterpillar Tractor Company. In essence, a two-lab cross-check on DOAS analysis, including extraction of the sample from the trap, LC separation and detection, as well as instrument calibration, was achieved.

Table 26 lists the results obtained during two days of testing of the Caterpillar 3208 EGR engine. Traditionally, one trap sample is obtained per run of which there are routinely 21 runs per odor measurement day, for steady-states only. The requirement to use larger amounts of solvent during the trap extraction step has decreased the concentration in the eluant by half. This forced the use of the more, sometimes most, sensitive ranges of the DOAS instrument, a condition to be avoided if at all possible. Several approaches were available, such as to load more sample on the trap by running each mode longer or sampling at a more rapid rate. The sampling rate was already near the maximum recommended, and the longer sampling periods are not compatible with the repetitive measurement of odor by the human panel.

The method desired as the best solution to maintain eluant concentration was to load each of the repeated runs on the same trap. This allowed three times the normal amount of exhaust to be passed through the trap and as such represented a composite of the operating condition. Thus, there are two types of DOAS trap sampling summarized on Table 26. On the top half of the table, both 3-trap average and 3-run composite data are listed for LCA and LCO in μg/ℓ and LCO in TIA units. The 3-trap average is based on the 21 individual traps, one for each run. The 3-run composite was a single trap, on which the three separate runs were collected. In practice, the trap would be removed and capped between repeated runs.

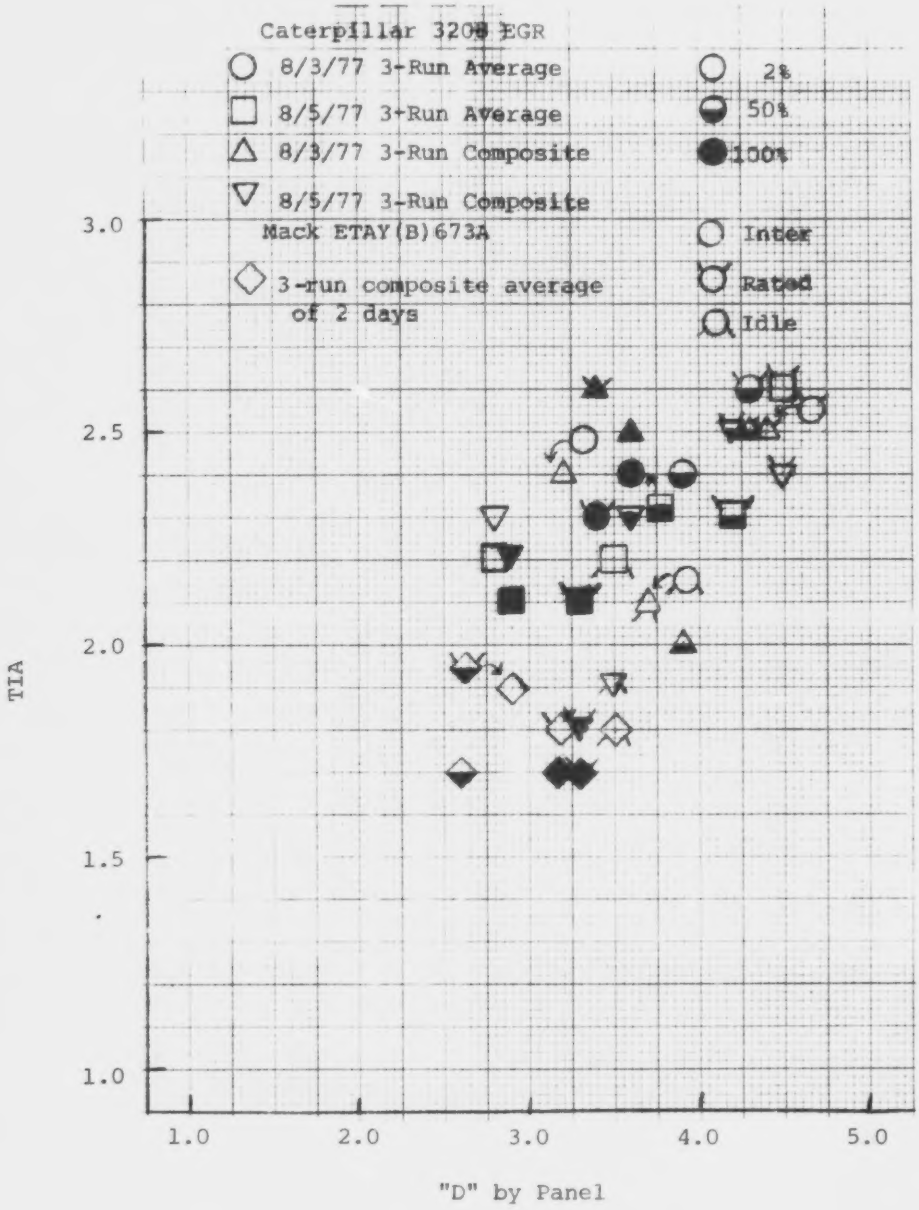

Figure 21a. "D" Odor Ratings Versus TIA
Mack ETAY(B)673A and Caterpillar 3208 EGR

TABLE 26. DOAS RESULTS - CATERPILLAR 3208 EGR

Engine rpm	Power %	3-Trap Average (One Run/Trap)			3-Run Composite (7 Traps)					
					SwRI			Caterpillar		
		LCA	LCO	TIA	LCA	LCO	TIA	LCA	LCO	TIA
				8/03/77						
Idle	---	24.85	12.39	2.08	20.52	11.77	2.07			
1680	2	59.74	25.42	2.39	58.59	24.61	2.39			
1680	50	55.66	23.06	2.35	15.83	11.04	2.04			
1680	100	30.66	22.91	2.36	60.77	30.29	2.48			
2800	2	64.42	36.19	2.56	53.83	29.02	2.46			
2800	50	51.69	39.93	2.59	47.59	29.77	2.48			
2800	100	33.84	18.68	2.25	83.86	37.08	2.57			
Average				2.37			2.36			
				8/05/77						
Idle	---	28.57	15.30	2.18	10.12	7.63	1.88	21.4	9.8	1.99
1680	2	32.81	17.87	2.25	35.99	17.75	2.25	35.5	15.3	2.18
1680	50	61.64	25.17	2.40	53.10	21.58	2.34	57.9	22.8	2.36
1680	100	20.89	13.50	2.11	23.02	14.71	2.17	22.1	12.2	2.09
2800	2	55.43	35.69	2.55	47.56	27.42	2.44	44.7	26.8	2.45
2800	50	32.44	24.09	2.33	39.32	30.77	2.49	35.9	24.8	2.39
2800	100	16.76	11.46	2.04	4.34	6.63	1.82	17.4	8.7	1.94
Average				2.27			2.20			2.20

LCA and LCO in μg/ℓ
TIA = 1 + $\log_{10}$ LCO

The extensive test series reported in Table 26 for both 8/03/77 and 8/05/77 by 3-trap average and 3-run composite data was performed to demonstrate equivalency between the two methods. These experiments were necessary prior to the adoption of the 3-run composite method of sampling for future DOAS use with Diesel powered cars and trucks/buses. Note that the overall average of the seven modes 3-trap average to 3-run composite TIA data was 2.37 versus 2.36 on 8/03/77 and 2.27 versus 2.20 on 8/05/77. The 3-run composite performed by SwRI and Caterpillar on 8/05/77 shows a 2.2 TIA value (overall 7-mode average). Not only were the overall values in complete agreement, but most of the modal values were also in agreement.

Figure 22 indicates the degree to which both DOAS sampling/analysis approaches (3-run composite versus 3-run average) agree. Note that the data are fairly symmetrical about a 45-degree line and quite close to a 1:1 relationship, certainly as close as would be anticipated by the DOAS system in general.

In summary of the Caterpillar 3208 DOAS data, it is clear that the 3-run composite gives equivalent or essentially equivalent results to that from the average of three individual traps. Consequently, the 3-run composite trap method is qualified and will be used on all future DOAS work. Another very important finding was the excellent correlation between DOAS analysis by Caterpillar and SwRI on 3-run composite samples, one for each of the seven modes tested. These samples were identically taken, simultaneously, and serve to validate the sample extraction, instrument calibration and use, as well as final results.

G. Aldehydes

Table 27 lists the aldehydes measured by the DNPH procedure for all three engines. In Section III, the DNPH procedure was described. The data on Table 27 are cycle composite rates based on the same seven test modes as used in the odor testing. The Diesel samples were taken at the same time as odor ratings, and test conditions were defined earlier in Table 24. The weighting factors used with the seven modes were derived from the 13-mode FTP and 23-mode EPA cycles. There is a substantial difference for several of the aldehydes between the two Diesels, namely, formaldehyde, acetaldehyde, acetone, and benzaldehyde. Isobutanal was substantially lower with the Caterpillar than the Mack engine.

Another way to compare the two Diesels would be to just add the individual rates without any additional weighting given to any aldehyde. These totals are shown on the bottom of Table 27 and indicate the Caterpillar to have 2.8 times (mg/kg fuel) and 2.5 times (mg/kw-hr) the Mack's "total" aldehydes. This is based on the factors derived from 13-mode FTP. From a review of this data, it is safe to say that the Caterpillar produced more aldehydes than the Mack engine.

A direct comparison of the Chevrolet 366 and Caterpillar 3208 engines may be made from Table 27. In this comparison, the Chevrolet engine had more formaldehyde, acetone, isobutanal, crotonal, hexanal and especially benzaldehyde. Some, if not most, of the differences noted are due completely to the differences in the fuels. The sum of the individual aldehyde rates for the Chevrolet was some 3.1 times (mg/kg fuel) and 6.4 times (mg/kw-hr) the Caterpillar

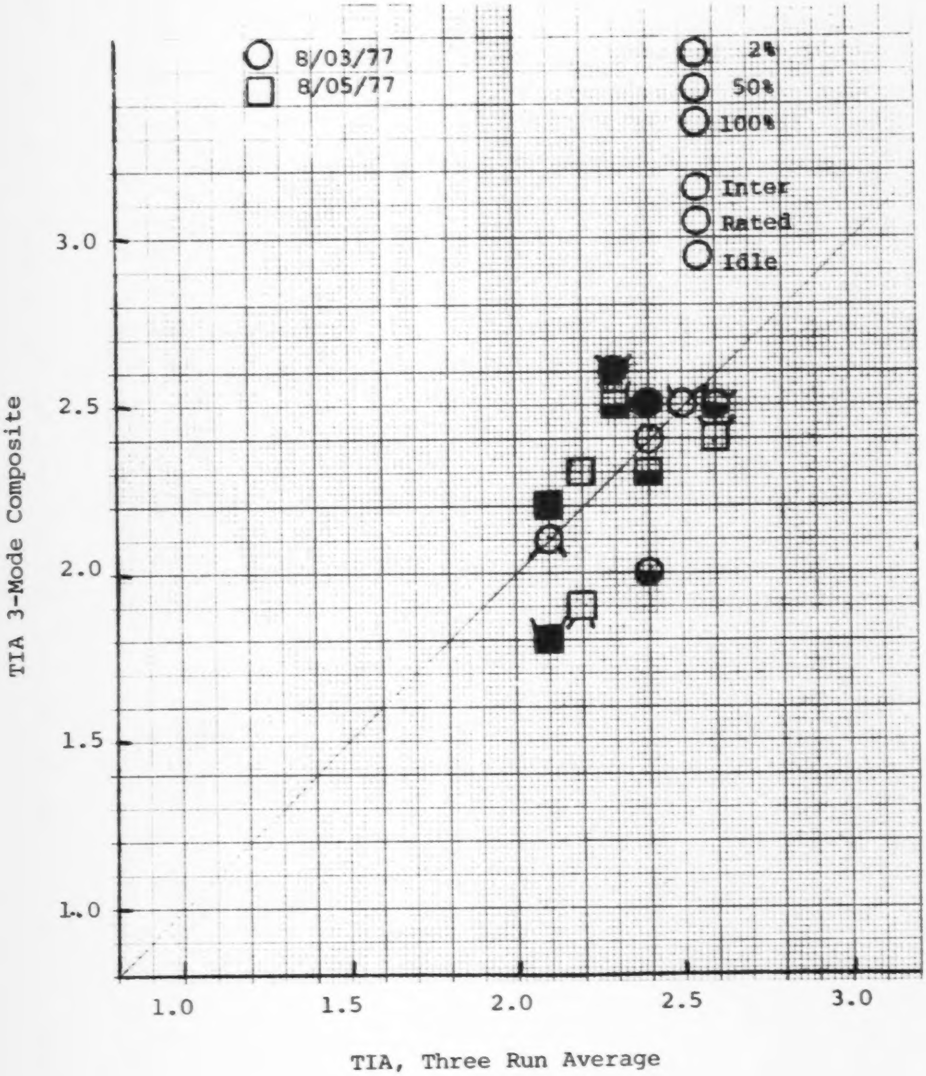

Figure 22. Comparison of TIA Values Based on 3-Run Average and 3-Run Composite Samples - Caterpillar 3208 EGR

TABLE 27. CYCLE COMPOSITE ALDEHYDE RATES

	Wgt.	mg/kw-hr			mg/kg fuel		
Aldehyde	Fact.	Mack	Cat	Chev	Mack	Cat	Chev
Formaldehyde	(1)	16.59	49.90	104.75	66.84	223.76	228.88
	(2)	19.02	43.90	105.36	77.78	191.23	221.08
Acetaldehyde	(1)	0.94	21.85	18.09	3.78	97.98	39.53
	(2)	0.88	19.25	21.27	3.43	83.85	44.64
Acetone	(1)	-----	12.55	18.40	------	56.28	40.20
	(2)	-----	11.58	24.09	------	50.43	50.54
Isobutanal	(1)	31.79	3.18	13.79	128.12	14.24	30.13
	(2)	33.61	2.45	18.05	130.34	10.68	37.87
Crotonal	(1)	16.68	19.16	587.87	67.22	85.91	1284.55
	(2)	19.03	17.76	810.01	73.80	77.37	1699.58
Hexanal	(1)	20.18	13.98	42.83	83.87	62.70	93.58
	(2)	24.47	14.46	38.18	94.89	62.98	80.11
Benzaldehyde	(1)	-----	95.65	595.67	------	428.89	1301.59
	(2)	-----	85.28	578.38	------	371.50	1213.56
Total	(1)	86.81	216.27	1381.40	349.83	969.76	3018.46
	(2)	97.01	194.68	1595.34	376.24	848.04	3347.38

Mack ETAY(B)673A, Caterpillar 3208/EGR, Chevrolet 366

(1) Based on weighting factors derived from 13-mode FTP.

(2) Based on weighting factors derived from 23-mode EPA.

engine. Based on weighting factors derived from the 23-mode EPA cycle, the ratios are 4.0 and 8.2. The difference in brake specific fuel economy of the two engines explains the differences in fuel and brake specific composite aldehyde rates.

For detailed results for each engine and test condition, please refer to Tables C-52 through C-54. Although odor was not measured with the Chevrolet engine, the same type of run conditions were measured as well as the two closed throttle modes. The run conditions for the Chevrolet 366 were described earlier on Table 21. For additional study and analysis, please refer to these appendix tables in which modal concentrations, mg/hr, brake and fuel specific individual aldehyde rates are listed.

H. Specific Hydrocarbons

Table 28 is a listing of the exhaust hydrocarbons, some of which are considered to be more or less nonreactive in the atmosphere in terms of the formation of photochemical smog. These measurements were made at each of the seven steady state operating points used for odor measurement. The engine operating data were previously listed on Table 24. For simplicity, the various hydrocarbons were computed in terms of cycle composite rates, again using weighting factors derived from the 13-mode FTP.

Ethylene and propylene were the two hydrocarbons with the highest brake and fuel specific rates from the Mack engine. Propane, ethane and toluene were the lowest rate hydrocarbons. The Caterpillar 3208 EGR engine had substantially higher rates than the Mack. Ethylene and propylene and methane were the highest rates. Propane, ethane and toluene were the lowest.

The consistency between the two Diesel engines, as far as high to low ranking, is quite interesting even though the levels were quite different between the two engines. A simple summation of the individual composites is shown on Table 28. Note the Caterpillar engine was 4.1 times the Mack mg/kg fuel and 3.8 times the Mack on a mg/kw-hr basis. These comparisons made use of the composites calculated using weighting factors derived from the 13-mode FTP.

The other important comparison to be made on Table 28 involves the Caterpillar and Chevrolet 366 engines. Methane was the hydrocarbon most plentiful from the Chevrolet 366, with toluene and ethylene next in rate. Propane was negligible. Compared to the Caterpillar, much more toluene, some 50 times more than the Diesel engine on a fuel specific basis, some 100 times more on the basis of mg/kw-hr, was emitted. Much more benzene as well as methane was also emitted by the Chevrolet 366.

Comparing the two engines based on the total of the eight hydrocarbons' individual rates shows the Chevrolet 366 to be some 3.6 times the Caterpillar in terms of mg/kg fuel and 7.4 times the Caterpillar in terms of mg/kw-hr. Using totals based on factors derived from the 23-mode EPA, the ratios are 4.8 and 9.9. The differences are consistent with the difference in brake specific fuel economy of the two different engines. Recall that the Chevrolet 366 engine ran on leaded gasoline without an oxidation catalyst.

TABLE 28. CYCLE COMPOSITE SPECIFIC HYDROCARBON RATES

Hydrocarbon	Wgt. Fact.	mg/kw-hr Mack	mg/kw-hr Cat	mg/kw-hr Chev	mg/kg fuel Mack	mg/kg fuel Cat	mg/kg fuel Chev
Methane	(1)	6.90	40.35	684.80	27.77	179.14	1498.70
CH_4	(2)	8.49	35.46	836.60	32.83	152.04	1762.53
Ethylene	(1)	45.03	158.04	422.96	181.18	701.69	925.67
C_2H_4	(2)	51.05	136.66	491.27	197.48	585.89	1035.01
Ethane	(1)	0.68	3.50	35.02	2.74	15.56	76.63
C_2H_6	(2)	0.67	3.00	41.81	2.60	12.84	88.09
Acetylene	(1)	2.79	22.83	149.04	11.24	101.35	326.18
C_2H_2	(2)	3.26	19.79	170.02	12.63	84.84	358.20
Propane	(1)	-----	0.18	5.43	------	0.79	11.89
C_3H_8	(2)	-----	0.16	6.21	------	0.70	13.09
Propylene	(1)	17.96	43.28	126.27	72.26	192.17	276.35
C_3H_6	(2)	19.32	37.74	141.53	74.75	161.81	298.16
Benzene	(1)	4.48	21.93	297.26	18.01	97.36	650.55
C_6H_6	(2)	4.88	18.60	348.78	18.86	79.74	734.79
Toluene	(1)	0.78	4.85	459.44	3.15	21.54	1005.49
C_7H_8	(2)	0.85	4.17	498.09	3.30	17.86	1049.38
Total	(1)	78.62	294.96	2180.22	316.35	1309.60	4771.41
	(2)	88.52	255.58	2534.31	342.45	1095.72	5339.25

Mack ETAY(B)673A, Caterpillar 3208/EGR, Chevrolet 366

(1) Based on weighting factors derived from 13-mode FTP.

(2) Based on weighting factors derived from 23-mode EPA.

Table 29 lists the methane fraction of the exhaust HC for each engine by test mode. The Mack ETAY(B)673A ranged from 0.78 to 2.8 percent with an overall average of 2.5 percent. The Caterpillar 3208 EGR engine ranged from 1.53 to 11.09 percent with an average of 3.5 percent. Note that the 11.09 percent methane fraction was at high speed, 2800 rpm, and half load. This value is exceptional and substantially different from all other Caterpillar and Mack methane percentages. Could it be that this specific point, where particulate was maximum, was caused by the large level of EGR used? The data point was carefully rechecked to verify that the methane value was right. It was found that most of the hydrocarbons were higher as may be noted from Table C-56.

The Chevrolet 366 methane fraction ranged from 0.31 at 1200 rpm closed throttle to 19.9 percent with an overall average of 4.7 percent. One mode, the 1200 rpm intermediate speed, was 19.9 percent methane. For additional modal data for all eight hydrocarbons, please refer to Tables C-55 through C-57.

TABLE 29. METHANE FRACTION OF EXHAUST HYDROCARBONS

Condition Speed, Load %	Engine[1]	Exhaust HC, ppmC	Methane ppmC	Methane Fraction %
Inter/02	Mack	209	3.3	1.58
	Cat	404	6.2	1.53
	Chev	57	3.6	6.32
Inter/50	Mack	123	1.1	0.89
	Cat	324	6.1	1.88
	Chev	100	19.9	19.9
Inter/100	Mack	62	0.6	0.97
	Cat	111	3.2	2.88
	Chev	1515	24.3	1.60
Inter/CT	Chev	10756	33.8	0.31
High/02	Mack	268	3.2	1.19
	Cat	575	11.3	1.97
	Chev	28	1.6	5.71
High/50	Mack	141	1.1	0.78
	Cat	412	45.7	11.09
	Chev	30	1.0	3.33
High/100	Mack	41	0.6	2.80
	Cat	28	0.7	2.50
	Chev	1044	33.2	3.18
High/CT	Chev	1408	14.3	1.02
Idle	Mack	212	3.5	1.65
	Cat	305	7.2	2.36
	Chev	2781	37.5	1.35

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(1) Mack ETAY(B)673A, Caterpillar 3208/EGR, Chevrolet 366

V. SULFATE AND PARTICULATE CHARACTERIZATIONS

This section describes the results of a variety of experiments to investigate, in a preliminary way, major engine changes on particulate and sulfate emissions from HDD engines. Table 30 is an evaluation matrix of the five effects of interest.

TABLE 30. EVALUATION MATRIX

Effect of Injection Timing	5° Advanced Standard 10° Retard	Caterpillar 3406 DI
Effect of EGR (Exhaust Gas Recirculation)	without EGR with EGR	Caterpillar 3406 DI (at Standard Timing)
Effect of Combustion System (at Standard Timing)	Direct Injection Indirect Injection	Caterpillar 3406 DI Caterpillar 3406 IDI
Effect of TC (Turbocharge)	with TC without TC	Daimler-Benz OM-352A TC Daimler-Benz OM-352 NA
Effect of Injection Pump	Standard R. Bosch APS A. Bosch	Mack ETAY(B)673A + Std. Mack ETAY(B)673A + APS

Each effect involved comparison of emissions in the following categories. Emission measurements were obtained in the order listed, even though sulfate and particulate effects were the most important.

- Smoke - FTP, 13-mode, power curve
- Gaseous emissions - 21-mode EPA, 13-mode FTP
- Particulate - 11-mode
  Sulfate - 11-mode
  BaP, organic solubles
  Hydrogen and carbon
  Metals
- Particle sizing
- DOAS
  Aldehydes
  Specific HC

Except for a few instances where the test could not be performed, a full matrix of emissions characterization data was obtained for each configuration listed in Table 30. Common configurations, such as the Caterpillar 3406 DI at standard timing, were tested only once.

A. Effect of Timing, EGR and Combustion System

These three effects were studied using the Caterpillar 3406 engine described in Section III. For simplicity, all the results will be listed for the five engine configurations and then, as subsections, the various effects will be discussed. Tables 31 and 32 list the smoke results for transient smoke cycle and steady state tests. Smoke was measured during every mode of the 13-mode FTP as well as during a full-power performance test.

TABLE 31. FEDERAL TRANSIENT SMOKE CYCLE OPACITY
CATERPILLER 3406

		Smoke opacity, %		
Configuration	Run	"a"	"b"	"c"
Direct Injection	1	13.9	6.7	24.8
Standard Timing	2	13.0	6.8	23.3
28° BTC	Avg	13.5	6.8	24.1
Direct Injection	1	18.9	16.1	21.4
10° Retarded	2	18.8	15.9	21.8
18° BTC	Avg	18.9	16.0	21.6
Direct Injection	1	10.4	3.3	22.9
5° Advanced	2	10.3	3.7	21.9
33° BTC	Avg	10.4	3.5	22.4
Indirect Injection	1	11.6	5.4	26.8
Standard Timing	2	12.2	5.3	30.5
BTC	Avg	11.9	5.4	28.6

Table 33 lists the results of the gaseous emissions tests by the 21-mode EPA procedure, with a 13-mode FTP result computed from the 21-mode data. For reference, the Caterpillar 3406 DI, as received from the manufacturer, had completed a 125-hour durability test. Data supplied by the manufacturer showed HC+NO$_2$ of 9.41, CO of 3.1 and HC of 0.44 g/hp-hr. When converted to g/kw-hr, the agreement is considered quite satisfactory, especially the HC+NO$_x$ value of 12.6 g/km-hr (9.41 ÷ 0.746) versus the 13.017 value on Table 33. The engine, as received, was at 27 degrees BTC static timing and within the timing tolerances. The slightly higher SwRI value was at 28 degrees BTC and is directionally correct, assuming the Caterpillar data were taken at 27 degrees BTC. Appendix Tables D-1 through D-17 are 21- and 13-mode computer printout sheets for the five Caterpillar 3406 configurations evaluated.

TABLE 32. STEADY-STATE SMOKE PERCENT OPACITY
CATERPILLAR 3406

	Timing °BTC Configuration		Direct Injection (DI)				Indirect Injection IDI Std. Timing(1)
			28 Std.	28 EGR	18 10° Ret.	33 5° Adv.	
			13-mode FTP steady states				
Mode	rpm	Power %					
1	Idle(2)	---	2.0	2.0	0.4	0.3	0.8
2	1260(3)	2	2.2	2.0	0.5	0.3	0.9
3	1260	25	2.5	9.0	2.9	1.7	1.0
4	1260	50	3.0	14.0	6.0	1.5	1.3
5	1260	75	3.5	15.0	8.0	2.5	3.0
6	1260	100	5.0	15.0	14.0	3.5	5.0
7	Idle(2)	---	1.5	1.5	0.3	0.6	0.6
8	2100	100	6.0	15.0	7.5	1.4	1.9
9	2100	75	3.5	15.0	7.0	1.0	1.8
10	2100	50	3.5	11.0	6.8	0.8	1.7
11	2100	25	3.2	6.0	5.9	0.8	1.6
12	2100	2	2.3	3.5	3.0	0.6	1.5
13	Idle(2)	---	2.0	2.0	0.4	0.6	0.6
			maximum power smoke				
	rpm						
	2100		5.6	not	10.5	1.3	1.2
	1900		6.0	run	11.0	1.3	1.9
	1700		6.5		11.0	1.3	2.6
	1500		7.6		13.0	1.5	4.8
	1300		9.0		16.5	2.0	6.0
	1260		9.4		16.5		
	1100		11.0			3.9	7.9

---

(1) 10° BTC Static Injection Timing
(2) DI 700 rpm, IDI 600 rpm
(3) IDI Intermediate Speed 1400 rpm

TABLE 33. GASEOUS EMISSIONS BY 13-MODE FTP AND 21-MODE EPA
CATERPILLAR 3406

Engine Configuration	Cycle	Run No.	Emission Rate, g/kW-hr				BSFC kg/kW-hr
			CO	HC	NO_2(a)	$HC+NO_2$	
			Direct Injection (DI)				
28° BTC Standard Timing	21 EPA	1	3.255	0.469	12.592	13.061	0.255
		2	2.383	0.428	12.544	12.972	0.253
		Avg	2.819	0.449	12.568	13.017	0.254
	13 FTP	1	3.564	0.417	12.437	12.854	0.253
		2	2.697	0.522	13.742	14.264	0.253
		Avg	3.131	0.470	13.090	13.559	0.253
EGR (28° BTC)	21 EPA		NOT RUN				
	13 FTP	1	6.434	0.229	7.345	7.574	0.268
18° BTC (10° Retard)	21 EPA	1	2.279	0.477	7.121	7.598	0.275
		2	3.713	0.515	6.968	7.482	0.275
		Avg	2.996	0.496	7.044	7.540	0.275
	13 FTP	1	2.431	0.404	6.904	7.309	0.273
		2	3.896	0.447	7.127	7.574	0.273
		Avg	3.164	0.426	7.016	7.442	0.273
33° BTC (5° Advance)	21 EPA	1	5.049	0.628	18.564	19.192	0.261
		2	4.692	0.623	18.162	18.794	0.261
		Avg	4.870	0.626	18.363	18.993	0.261
	13 FTP	1	5.872	0.540	19.100	19.640	0.263
		2	5.395	0.526	17.969	18.495	0.262
		Avg	5.634	0.533	18.534	19.068	0.262
			Indirect Injection (IDI)				
Standard Timing	21 EPA	1	2.049	0.234	7.059	7.292	0.275
		2	1.413	0.193	6.830	7.022	0.275
		Avg	1.731	0.214	6.944	7.157	0.275
	13 FTP	1	1.428	0.153	6.806	6.959	0.273
		2	1.939	0.176	6.950	7.126	0.272
		Avg	1.684	0.164	6.878	7.042	0.272

---

[a] NO_x as NO_2 by CL - 21-mode EPA
NO as NO_2 by NDIR - 13-mode FTP

Table 34 lists the particulate and sulfate rates for the Caterpillar 3406 experiments. These are brake specific and fuel specific results using the 13-mode test conditions. Tables D-18 through D-41 list the modal results for each of the five configurations, as well as the brake specific and fuel specific computation sheets. Percent conversion of fuel sulfur to that measured as sulfate in the exhaust is also listed.

TABLE 34. SULFATE AND PARTICULATE EMISSION RATES
(BASED ON 13-MODE CYCLE)
CATERPILLAR 3406

		Brake Specific		Fuel Specific	
Engine Configuration	Run No.	Particulate g/kW-hr	Sulfate mg/kW-hr	Particulate g/kg fuel	Sulfate mg/kg fuel
Direct Injection	1	0.464	28.09	1.824	110.47
Standard Timing	2	0.475	28.18	1.872	111.05
28° BTC	3	0.466	29.16	1.841	115.11
	Avg	0.468	28.48	1.846	112.21
Direct Injection	1	1.232	28.14	4.600	105.09
EGR	2	1.229	27.30	4.598	102.09
28° BTC	3	1.272	30.58	4.770	116.46
	Avg	1.244	28.67	4.656	107.88
Direct Injection	1	1.310	37.79	4.801	138.53
10° Retard	2	1.379	37.23	5.066	136.76
18° BTC	3	1.400	36.63	5.137	134.38
	Avg	1.363	37.22	5.001	136.56
Direct Injection	1	0.347	33.42	1.322	127.26
5° Advance	2	0.361	35.22	1.375	134.17
33° BTC	3	0.373	34.64	1.420	131.76
	Avg	0.360	34.43	1.372	131.06
Indirect Injection	1	0.362	41.88	1.331	154.10
Standard Timing	2	0.374	40.04	1.383	147.97
10° BTC	Avg	0.368	40.96	1.362	151.04

Results of BaP and organic content of the 8 x 10 size filters, reported by Dr. Jungers of EPA-RTP, are listed on Table 35 in terms of brake and fuel specific emission rates. These rates used weighting factors derived from the 13-mode FTP and 21-mode EPA cycles applied to the seven individual modes sampled. Appendix Table D-42 contains individual 7-mode results while Tables D-43 through D-47 are the composite rate calculations. The seven modes were idle, 2, 50 and 100 percent of power at 1260 and 2100 rpm.

Table 36 contains the carbon and hydrogen content of the 47 mm fiberglass filter collected particulate. These analyses were performed on the same 7 modes used for BaP and organic extract. Table D-48 contains the results of

TABLE 35. BaP AND ORGANIC SOLUBLE FRACTION OF
PARTICULATE COLLECTED ON 8 x 10 FILTER, 7-MODE TEST
CATERPILLAR 3406

Configuration	Cycle	Brake Specific BaP μg/kw-hr	Fuel Specific BaP, μg/kg fuel	Cycle Org. Sol.,%
Direct Injection, Open Chamber				
Std. Timing	13	0.197	0.768	17.85
28° BTC	21	0.270	1.031	17.60
Std. Timing	13	0.105	0.399	19.48
+ EGR	21	0.136	0.501	21.08
10° Retard	13	0.690	1.993	19.15
18° BTC	21	0.958	3.093	21.19
5° Adv.	13	1.256	4.768	12.87
33° BTC	21	1.869	6.994	11.61
Indirect Injection, Pre-chamber				
Std. Timing	13	0.143	0.524	11.14
10° BTC	21	0.172	0.608	10.50

TABLE 36. CARBON AND HYDROGEN CONTENT OF PARTICULATE CATERPILLAR 3406

		Direct Injection DI				Indirect Injection
Condition Speed/Load %		28 Std.	28 EGR	18 10°Ret.	33 5° Adv.	Std. Timing
1260/2	C	43.30	45.09	39.32	44.07	59.97
	H	5.22	4.28	4.79	5.38	4.50
	H/C(1)	1.44	1.13	1.45	1.45	0.89
1260/50	C	63.84	84.43	91.45	51.62	57.33
	H	2.92	0.70	1.64	2.46	2.66
	H/C	0.55	0.10	0.21	0.57	0.55
1260/100	C	78.74	78.52	92.63	71.30	82.86
	H	0.86	0.78	0.76	<0.3	1.40
	H/C	0.13	0.12	0.10	0.05	0.20
Idle	C	33.96	43.09	53.42	67.94	50.96
	H	3.55	4.80	6.32	5.82	2.36
	H/C	1.25	1.33	1.41	1.02	0.55
2100/100	C	68.76	83.93	85.40	53.64	48.29
	H	1.37	0.82	1.14	1.99	1.27
	H/C	0.24	0.12	0.16	0.44	0.31
2100/50	C	67.13	82.87	81.52	50.79	63.34
	H	1.97	1.36	1.42	3.43	2.91
	H/C	0.35	0.20	0.21	0.80	0.55
2100/2	C	47.24	69.40	74.18	49.73	71.30
	H	6.49	3.54	4.40	6.70	5.63
	H/C	1.64	0.61	0.71	1.61	0.94

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(1) H/C Mole Ratio

the metals analyses performed by RTP for each Caterpillar 3406 configuration tested. The plastic Fluoropore filters, representing each of the eleven different modes of the 13 mode-test, were used for this analysis.

Table D-49 is an overall summary of the percent per stage of total particulate collected by an Anderson Model 50-810 impactor. For the Caterpillar engine, the impactor assembly was located outside of the tunnel and a special series of tests made using seven modes of the 13-mode schedule. Figure 23 shows several views of the Anderson impactor, while Figure 24 shows the various filter stages. Preweighted, clean, stainless steel impactor discs were used for collection of dilute exhaust particulate. The use of this 0.051 mm (0.002-inch) thick stainless steel foil as the collecting stage was first employed with Diesel exhaust in EPA Contract No. 68-03-2440.(44)

Impactor flow was maintained at approximately 0.021 m^3/min (0.75 acfm) during isokinetic tunnel sampling to provide individual-stage Effective Cutoff Diameters (ECD) from 0.42 to 10.9 microns. The exhaust sample containing a mixture of particle shapes and densities is fractionated and collected according to its aerodynamic characteristics and is therefore aerodynamically equivalent in size to the unit density calibration spheres (1 g/cc) collected on each specific stage. The aerodynamic size of a particle gives information about its physical size, shape, and density. It thus indicates how the particle will behave in any environment.

Figures D-1 through D-5 are plots of the particle size data, one figure for each configuration. These plots illustrate the individual modal size distributions.

Table 37 is a summary of DOAS values measured during a 7-mode cycle. Brake and fuel specific results for the seven aldehydes by the DNPH procedure are summarized for the 7-mode test on Table 38. Modal data are given in Tables D-50 through D-54. Table 39 lists the specific hydrocarbon data in mg/km-hr and mg/kg fuel burned using weighting factors derived from the 13-mode FTP. This summary is based on the 7-mode test data contained in Tables D-55 through D-59.

1. Effect of Timing

The static pump fuel injection timing was varied from the standard 28 degrees BTC to investigate the effect of this parameter on particulate, sulfate and other emissions. These experiments were done with the engine in the DI configuration.

a. Smoke

In general, advanced timing reduces visible smoke, while retarded timing increases visible smoke emissions. This engine followed this well-established relationship as shown by the Table 31 "b" "lug-down" smoke factor and on Table 32 during the 13-mode and full-power opacity readings. The "b" factors are compared below.

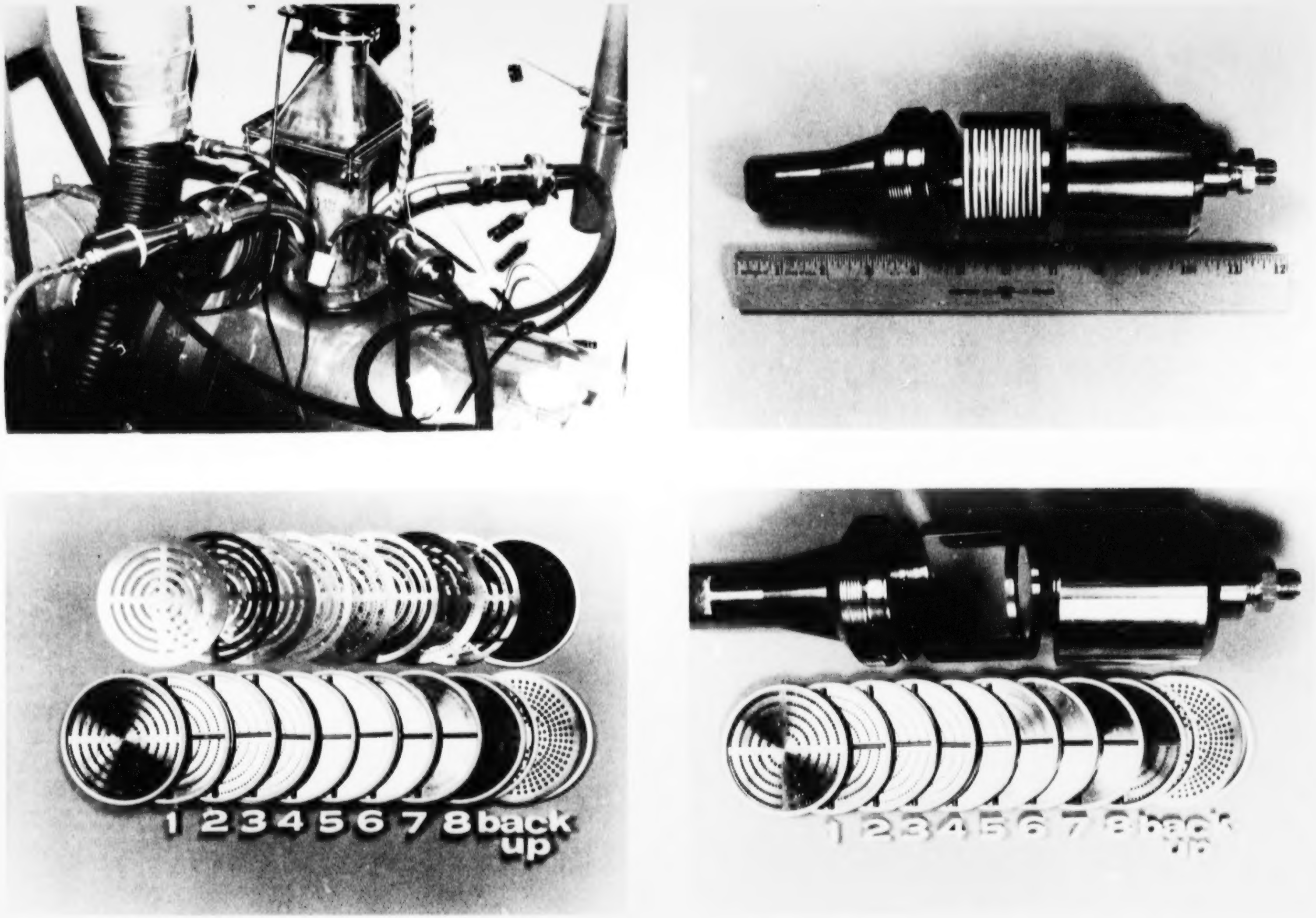
12
1 2 3 4 5 6 7 8 back up
1 2 3 4 5 6 7 8 back up

Figure 23. Anderson Mark III In-Stack Sampler - Used for Diesel Particle Sizing

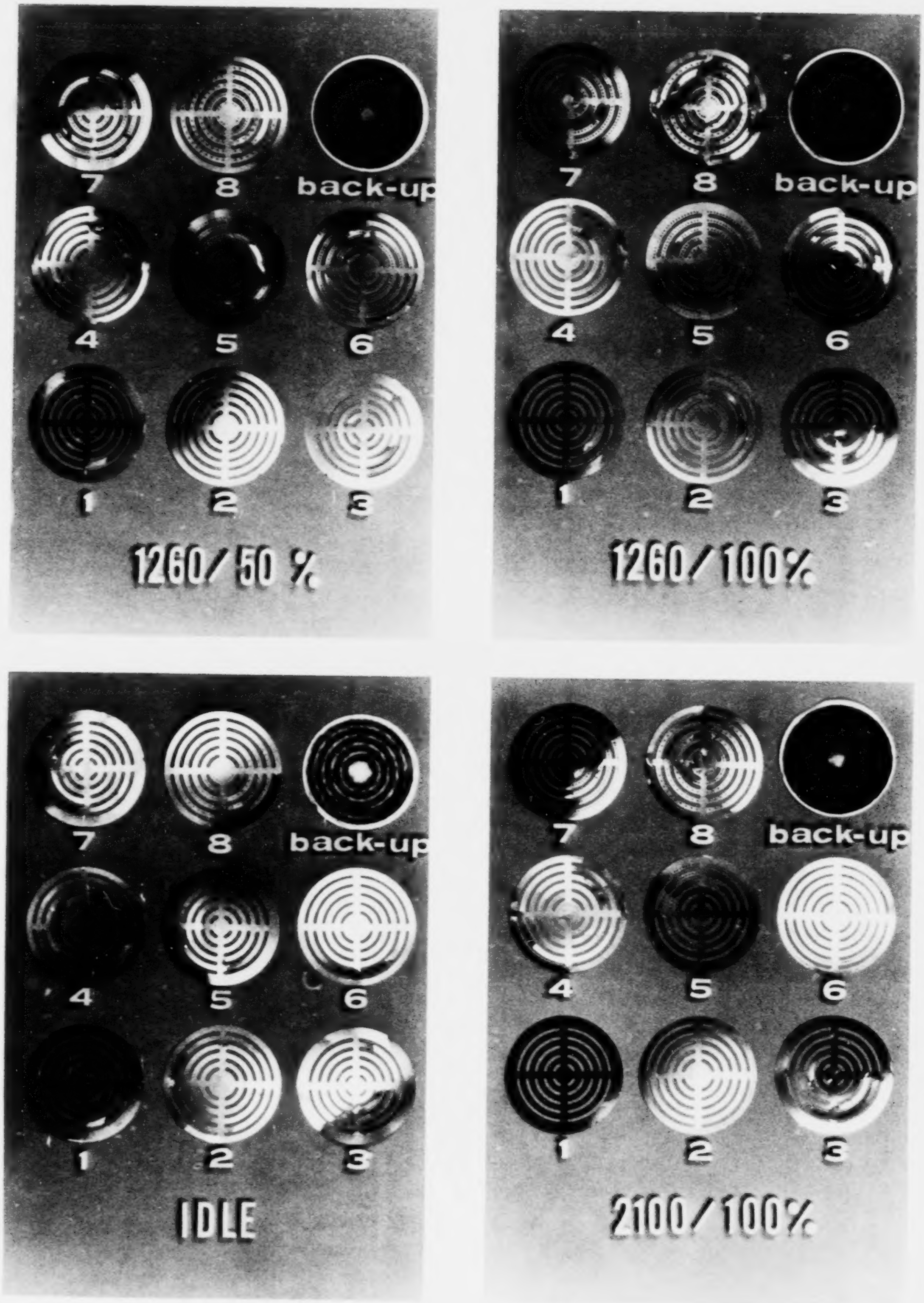
7
8
back-up
4
5
6
1
2
3
1260/50 %
7
8
back-up
4
5
6
1
2
3
1260/100%
7
8
back-up
4
5
6
1
2
3
IDLE
7
8
back-up
4
5
6
1
2
3
2100/100%

Figure 24. Anderson Impactor Stage Collection Foils and Back-up Filter

TABLE 37. DOAS RESULTS FOR CATERPILLAR 3406 DIESEL

Configuration	DOAS[a]	1260 rpm			600[b]	2100 rpm		
		2	50	100	Idle	100	50	2
Std DI Engine	LCA	25.0	13.8	1.7	21.5	4.8	4.3	18.2
28° BTC	LCO	17.2	8.8	5.4	15.4	6.0	4.5	11.0
Timing	TIA	2.2	2.0	1.7	2.2	1.8	1.7	2.0
Std DI Engine	LCA	29.5	11.8	4.0	39.3	5.5	6.5	18.1
33° BTC	LCO	19.1	5.4	2.6	27.2	5.5	4.4	12.9
Timing	TIA	2.3	1.7	1.4	2.4	1.7	1.7	2.1
Std DI Engine	LCA	25.2	10.6	1.8	5.4	1.3	21.7	30.2
18° BTC	LCO	7.6	4.5	0.9	2.1	1.3	10.7	13.9
Timing	TIA	1.9	1.7	1.0	1.3	1.1	2.0	2.1
EGR DI Engine	LCA	7.4	3.1	0.4	9.9	2.2	4.4	15.1
28° BTC	LCO	5.9	3.3	1.2	7.3	2.7	4.0	11.9
Timing	TIA	1.8	1.5	1.1	1.9	1.4	1.6	2.1
			1400 rpm					
Std IDI Engine	LCA	7.0	3.2	3.8	2.6	3.1	3.4	1.9
10° BTC	LCO	6.8	1.6	3.4	3.1	1.1	1.0	1.3
Timing	TIA	1.8	1.2	1.5	1.5	1.0	1.0	1.1

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[a] LCA and LCO in µg/litre

[b] IDI idle speed is 700 rpm

TABLE 38. BRAKE AND FUEL SPECIFIC ALDEHYDE RATES CATERPILLAR 3406

Aldehyde	Direct Injection Std.Tim. 28° BTC	EGR 28°BTC	10°Ret. 18°BTC	5° Adv. 33°BTC	Indirect Inj. Standard Tim. 10° BTC
Formaldehyde, mg/kw-hr	25.83	16.77	34.42	66.28	18.91
mg/kg fuel	96.10	63.45	124.31	251.5	68.05
Acetaldehyde, mg/kw-hr	3.49	0.69	14.71	9.17	8.47
mg/kg fuel	13.00	2.61	53.10	34.8	30.47
Acetone, mg/kw-hr	2.47	0.06	3.59	15.02	2.56
mg/kg fuel	9.18	0.21	12.97	57.0	9.23
Isobutyraldehyde, mg/kw-hr	19.87	18.16	7.93	15.58	4.74
mg/kg fuel	73.93	68.72	28.64	59.1	17.07
Crotonaldehyde, mg/kw-hr	26.26	38.92	15.98	93.99	17.31
mg/kg fuel	97.70	147.25	57.70	356.6	62.29
Hexanaldehyde, mg/kw-hr	6.27	19.35	13.88	76.58	5.74
mg/kg fuel	23.35	73.23	50.13	290.6	20.67
Benzaldehyde, mg/kw-hr	13.71	13.00	74.61	49.70	49.13
mg/kg fuel	51.02	49.17	269.42	188.6	176.83
Total Aldehyde, mg/kw-hr	97.90	106.95	165.12	326.32	106.86
mg/kg fuel	364.28	404.64	596.27	1238.2	384.61

TABLE 39. BRAKE AND FUEL SPECIFIC HYDROCARBON RATES CATERPILLAR 3406

Hydrocarbon	Std.Tim. 28° BTC	EGR 28°BTC	10°Ret. 18°BTC	5° Adv. 33°BTC	Indirect Inj. Standard Tim. 10° BTC
Methane, mg/kw-hr	18.25	13.17	18.68	22.90	6.51
mg/kg fuel	68.95	49.83	67.29	86.88	23.45
Ethylene, mg/kw-hr	67.34	52.43	62.58	83.81	38.42
mg/kg fuel	254.48	198.38	225.98	318.01	138.28
Ethane, kg/kw-hr	1.16	0.96	1.33	1.60	0.12
mg/kg fuel	4.40	3.62	4.79	19.90	0.43
Acetylene, mg/kw-hr	6.58	6.60	5.96	8.46	4.65
mg/kg fuel	24.88	24.99	21.51	32.10	16.72
Propane, mg/kw-hr	BMD	BMD	0.09	0.06	0
mg/kg fuel	BMD	BMD	0.31	0.24	0
Propylene, mg/kw-hr	21.72	14.49	20.28	24.45	10.95
mg/kg fuel	82.08	56.33	73.22	92.76	39.40
Benzene, mg/kw-hr	7.22	7.62	11.45	8.32	4.28
mg/kg fuel	27.30	28.85	41.35	31.57	15.40
Toluene, mg/kw-hr	2.03	1.68	2.09	1.02	3.45
mg/kg fuel	7.69	6.36	7.53	3.87	12.41
Total Hydrocarbon, mg/kw-hr	124.30	96.95	122.41	150.62	68.38
mg/kg fuel	469.78	368.36	441.98	585.33	246.09

BMD: Below Minimum Detectable

Static Timing	"b" Lug Down, % Opacity
5° Advanced	3.5
Standard Timing	6.8
10° Retarded	16.0

To the extent that full-power smoke can be related to engine particulate, the mass emissions of particulate shown follow this trend. Particulate is produced under part-load conditions also, but the very low smoke readings during the less than 100 percent power modes of the 13-mode FTP shows the difficulty of using opacity readings to determine exhaust particulate.

b. Gaseous Emissions

The general effect of timing on NO_x emissions is opposite to that of smoke, and this was clearly shown by the timing data on Table 33. For comparison, the average 13-mode results are listed below.

	g/kw-hr		
Static Timing	CO	HC	NO_2
5° Advanced	5.6	0.53	18.5
Standard Timing	3.1	0.47	13.1
10° Retarded	3.2	0.42	7.0

The effect on CO is interesting but of no significance since CO is already negligible. The effect on HC is considered very slight if at all. But, the effect on NO_2 is large and quite consistent with other published data for Diesel engines. Thus, a trade-off must be made between NO_2 and smoke for most Diesel engines for basic fuel injection timing. Standard timing, on this engine, gave the best cycle BSFC with operation at either the advanced or retarded settings resulting in increased fuel consumption. This is normal.

c. Particulate and Sulfate

The 13 mode-cycle is a quick way to summarize the effect of timing. Using brake specific results from Table 34, the trends are consistent in terms of particulate, namely an increase in particulate as timing was retarded, just like visible smoke.

Basic Timing	Particulate g/kw-hr	Sulfate mg/kw-hr
5° Advanced	0.36	34.4
Standard Timing	0.47	28.5
10° Retarded	1.36	37.2

This is illustrated in the lower half of Figure 25 for both brake and fuel specific 13 mode-rates.

Sulfate emissions, plotted in the upper half of Figure 25, demonstrated no such clear trend as did particulate, the results being somewhat indicative of the BSFC trend, lowest sulfate at the standard timing, higher

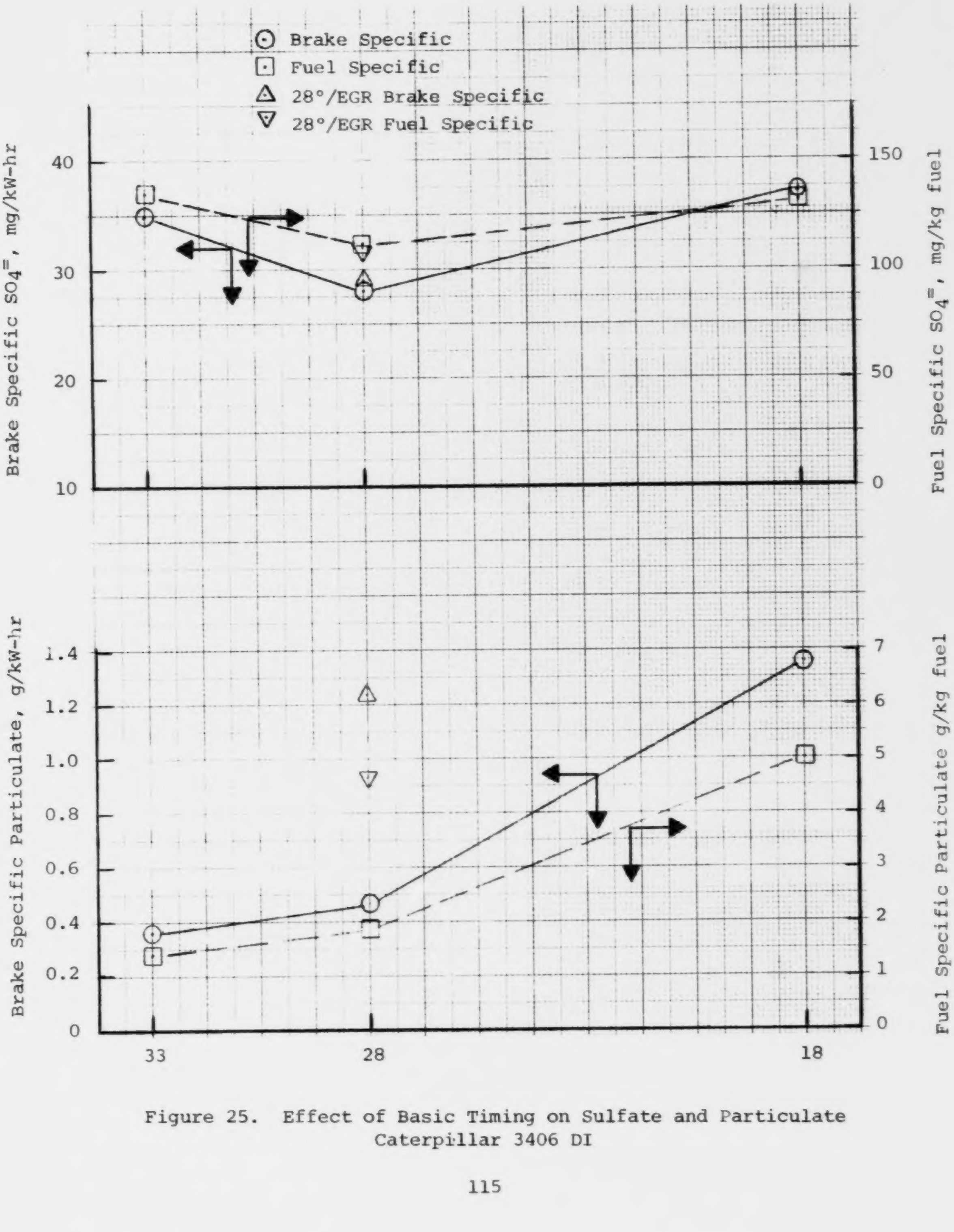


Figure 25. Effect of Basic Timing on Sulfate and Particulate
Caterpillar 3406 DI

sulfate at advanced and retarded positions. The values are not so different, however, to indicate any effect, considering the method of measurement.

A plot of particulate and sulfate mass rates from averages of data in Tables D-18, D-19, D-28, D-29, D-33 and D-34 is given in Figure 26. The 10° retard condition clearly resulted in the highest particulate rate of three timings run. As timing was advanced, particulate decreased, with the 5-degree advance condition producing the lowest particulate. These trends and the relationship of more particulate at higher power conditions are consistent. Sulfate mass rate also increased with power level and fuel rate, as is typical, since sulfate seems to be on the order of 1-2 percent of the fuel sulfur burned. Above 50 percent power there appears to be some differences shown versus timing setting, per Figure 26. The differences are not consistent. For example, at 2100 rpm the 10-degree retard gave the highest and standard timing the lowest rate.

The following summarizes the maximum, minimum and average sulfate conversion based on modal data listed in Tables D-19, D-29 and D-34.

	Fuels measured as $SO_4^=$, %		
Timing, °BTC	Max.	Min.	Avg.
33 (5° Advanced)	5.27(1)	1.57	2.24
28 (Standard Timing)	4.13(1)	1.22	1.86
18 (10° Retarded)	2.47	1.40	1.98

---

(1) Idle

The differences in average sulfate conversion are considered small, almost negligible. The trend, if there is any, is somewhat consistent with the mg/kw-hr sulfate, i.e., lowest at standard timing.

d. BaP and Organic Soluble Fraction

The effect of timing is highlighted by the following, from Table 35, based on 13-mode weighting.

	Cycle Composite	
Timing	BaP, μg/kw-hr	Org. Sol., %
33° (5° Advanced)	1.26	12.9
28° (Standard Timing)	0.20	17.9
18° (10° Retarded)	0.69	19.2

From the above it is evident that 5-degree advanced timing gave the highest brake specific BaP rate and the lowest organic soluble fraction of the particulate. An interesting inference from this is that increased BaP content is not necessarily a function of increased organic soluble fraction of the particulate. Standard timing resulted in the lowest BaP level, with the 10-degree retard giving a level halfway between. The computation of a cycle composite, based on 7-mode results, is helpful in obtaining an overall value for the partial map type data. Weighting factors are merely applied to the modal percent organic data to obtain a cycle weighted value.

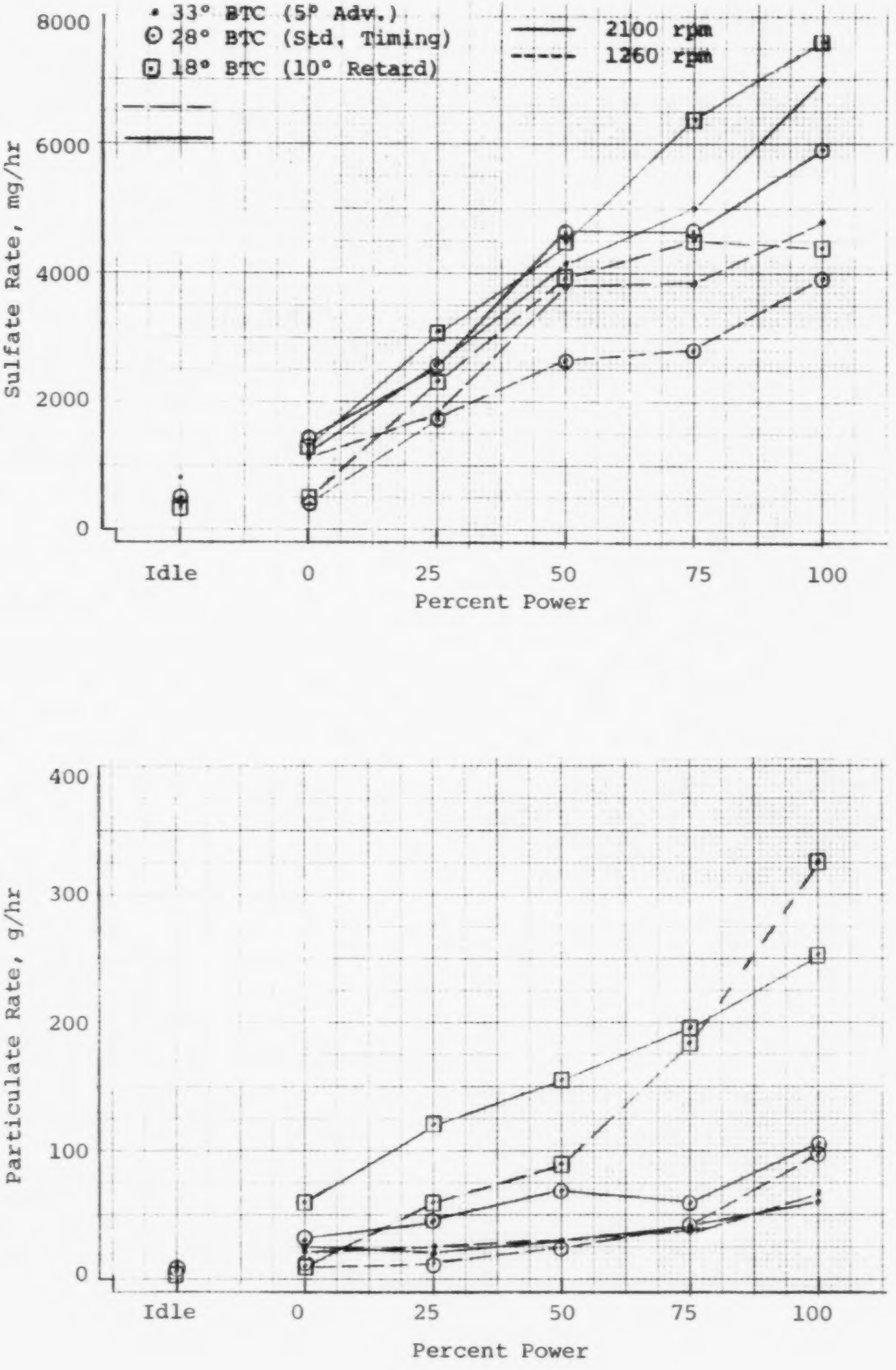


Figure 26. Particulate and Sulfate Modal Rates for Different Static Injection Timings, Caterpillar 3406 DI

e. Hydrogen, Carbon and Metal Content

From data on Table 36, the computer hydrogen/carbon mole ratio can be used to see if timing had an effect. The range as well as average value obtained from elemental analyses of the 47 mm glass fiber filters are listed below.

	H/C Mole Ratio		
Configuration	Max.	Min.	Avg.
33° (5° Advanced)	1.61	0.05	0.85
28° (Standard Timing)	1.64	0.13	0.80
18° (10° Retarded)	1.45	0.10	0.61

The smaller the H/C ratio, the more carbon, or less hydrogen, content on the filter. Even though the changes in timing did not make a large change in the average H/C ratio, the retarded condition average of 0.61 is somewhat below the other two conditions. This means that the increased gross particulate, with retarded timing (discussed earlier), was due to an increase in carbonaceous relative to hydrogen material on the filter. In reviewing the data on Table 36, it is interesting to note the change in H/C mole ratio increases; thus, the minimum values listed above are for maximum power, and the maximum H/C values are for light loads such as 2 percent power. For reference, Diesel fuel H/C mole ratios are typically 1.6 to 1.7.

Looking at the metals analyses on Table D-48, it is evident that phosphorus, sulfur, chlorine and calcium were most consistently found, with some iron, silica, and trace of aluminum. It is difficult to attribute the presence, absence or amount of these metals to a change in timing. The sulfur values are of some interest but have already been commented on in terms of sulfate by the BCA method.

f. Particle Sizing

Figure 27 illustrates the effect timing changes had on size distribution. For simplicity, the arithmetic average of the seven modes listed on Table D-49 was plotted to give an overall view of trends, if any. Each line on the graph represents the unweighted average of the modal size distributions for that configuration. Standard and advanced timing show the closest agreement as might be expected since the timing difference was only 5 degrees. Retarded timing shows a slight shift to the right indicating that slightly smaller size particles were produced with this timing condition.

From this comparison it is evident that the timing changes had no substantial effect on particle sizing, at least in the size range that was measurable by the Anderson impactor. It is also very evident that the particle sizes are, for the most part, very small. This is highlighted below.

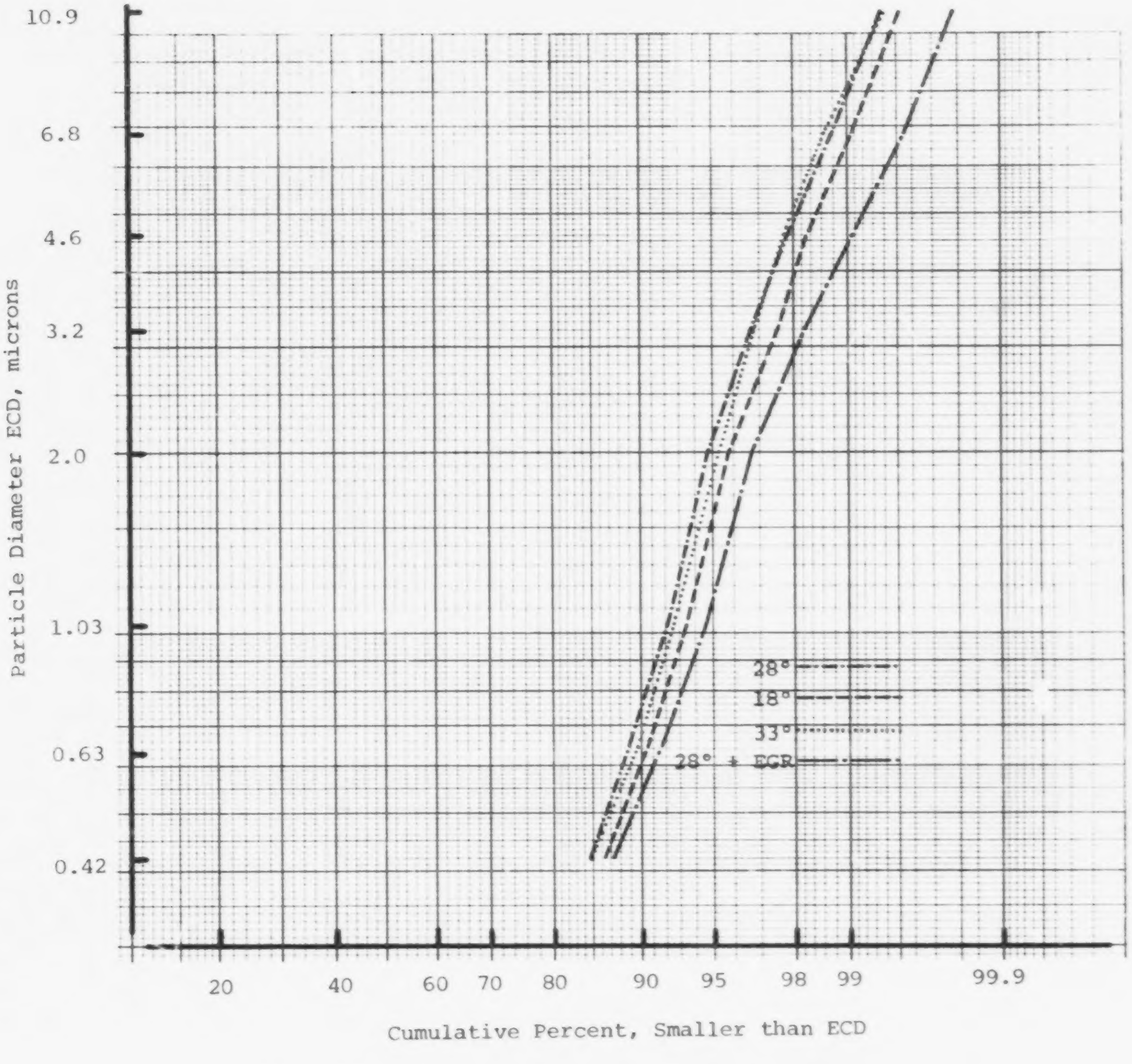


Figure 27. Particle Size Distributions by "Means" for Caterpillar 3406 DI, via Impactor

Particle Diameter ECD Microns	Cumulative Percent Smaller than ECD
less than 10	99.3 - 99.5
5	98.0 - 98.5
2	94.6 - 95.8
1	92.0 - 93.3
0.5	88.0 - 90.0
0.42	84.8 - 86.5

It is the very large 85 or so percent of the particulate less than 0.42 micron ECD, caught on the backup filter in the impactor and not classified, that is of interest. The 92-93 percent below one micron means that nearly all the Diesel exhaust particulate, as sized by the Anderson method, is very light and fine and considered easily respirable.

For additional plots of the modal results, please refer to Figures D-1, D-3 and D-4. These modal plots show some interesting trends such as greater variability in the 2-micron-and-less size with mode for 5-degree advance, Figure D-4. But, in total, the size distribution lines are sufficiently close to one another as to make it difficult to draw conclusions. Remember, these distributions represent only about 15 percent of the particulate in the first place.

g. DOAS

Figure 28 is a plot of the TIA values from Table 37 versus power level for both rated and intermediate speeds. Retarded timing appeared to have lower TIA values, but no overall trend to this effect is clearly evident. The only obvious trend is TIA decreased as power increased for most cases. In two cases, the 28-degree, 2100 rpm and the 33-degree, 2100 rpm , the 50 percent and 100 percent power TIA values were essentially the same.

As a simplified summary, the following compares LCO for each configuration by simply averaging the 7 mode results and listing the maximum and minimum. Also listed is the TIA computed from this average.

	LCO, μg/litre			TIA
Static Timing, °BTC	Max.	Min.	Avg.	Avg.
33 (5° Advanced)	27.2	2.6	11.0	2.0
28 (Standard Timing)	17.2	4.5	9.8	2.0
18 (10° Retarded)	13.9	0.9	5.9	1.8

In terms of TIA, the differences in LCO between the 10-degree retard and the other two timing conditions disappear. The retarded timing did, however, result in lowest LCO and TIA of the three, and this is of some interest.

h. Aldehydes

One way to see if static fuel injection timing affects the aldehydes is to add together the individual mg/kw-hr values on Table 38. These are shown below based on 7-mode test using weighting factors derived from the 13-mode FTP.

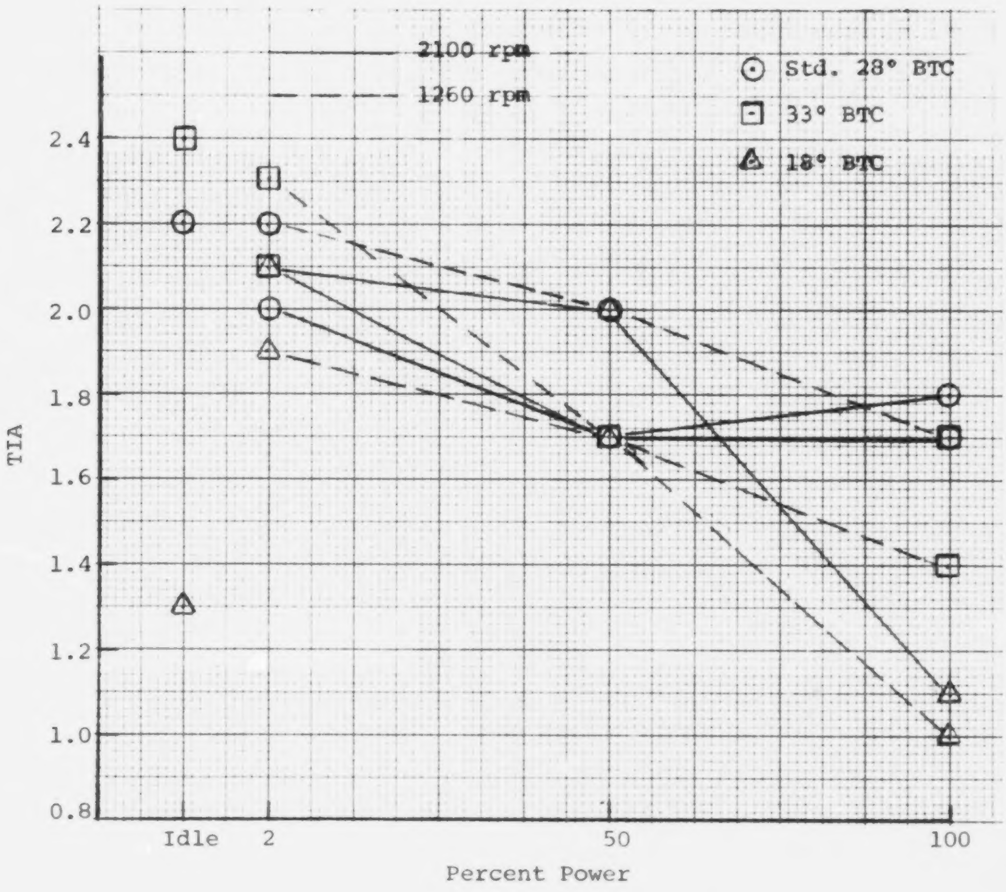


Figure 28. Effect of Timing on TIA
Caterpillar 3406 DI Version

Timing	Aldehydes mg/kw-hr	LCA, Avg. µg/litre
33° BTC (5° Advanced)	326.3	16.4
28° BTC (Standard Timing)	97.9	12.8
18° BTC (10° Retarded)	165.1	13.7

The above indicate that standard timing produces the lowest aldehydes of the three conditions. This is interesting since BaP, another intermediate combustion product, was lowest at standard timing (see subparagraph d earlier in this section). Sulfate seemed to have the same trend of lowest value at standard timing, but there is no obvious reason for such a connection.

Aldehydes are, for the most part, odorous compounds, and such a trend as shown above might also be shown by the DOAS results. It was not, however, in terms of LCO or TIA. In terms of LCA, the average values are listed above and show that the average LCA was lowest at standard timing. Possibly a connection exists between the liquid column aromatic fraction of the DOAS and the aldehydes as measured by the DNPH method. From Table 38 it should be noted that the same trend of 33 degrees highest, 28 degrees lowest, and 18 degrees in between was found for formaldehyde, acetone and hexanaldehyde. Although the 33-degree and 18-degree values were not consistent as to which was highest, the 28-degree timing was lowest except for isobutyraldehyde and crotonaldehyde. Tables D-50, D-52 and D-53 provide individual mode data for further analysis.

i. Specific Hydrocarbons

As with the aldehydes, it is instructive to see if timing had an effect on the eight different hydrocarbons as a group. The following compares the sum of the brake specific rates from Table 39 (7-mode test using weighting factors derived from 13-mode FTP).

Static Timing	Sum of Specific Hydrocarbons, mg/kw-hr
33° BTC (5° Advanced)	150.6
28° BTC (Standard Timing)	124.3
18° BTC (10° Retarded)	122.4

It is clear that the changes in timing had essentially no effect on the aggregate of the eight specific hydrocarbons measured. A review of the individual brake specific rates, Table 39, shows this to be pretty much the case throughout. In some instances, such as ethylene and acetylene, the 5-degree advance resulted in noticeably higher values than the other two timings. Benzene was highest with the 10-degree retard conditions. More detailed study of the specific hydrocarbons can be made from Table D-55, D-57 and D-58

j. Summary

The major effect of timing on the Caterpillar 3406 DI has been to increase particulate with retarded timing. This is consistent with the well-known effect of timing retard on increasing visible smoke and reducing oxides of nitrogen. No major or obvious effects were noted on sulfate, particle sizing, DOAS, or specific hydrocarbons. BaP and aldehydes were lowest at standard timing, highest at 5 degrees advanced timing and in between at the 10-degree retarded timing setting.

2. Effect of EGR

Exhaust gas recirculation is a well-known technique for reduction of oxides of nitrogen. It is typically applied to Diesel engines at output levels less than full power to prevent an increase in maximum power smoke. A Caterpillar 3208 Diesel, with production EGR, was evaluated in Section IV of this report. The Caterpillar 3208 sold in California is the only production HDD engine with automatic EGR.

For purposes of this experiment to determine the effect of substantial EGR on particulate and sulfate, a manual EGR system was fabricated and installed. A large, 101.6 mm (4-inch) exhaust pipe connected to the engine's 127 mm (5-inch) exhaust pipe ducted hot exhaust directly into the turbocharger air intake. A large, 76.2 mm (3-inch) gate valve was used to regulate the amount of exhaust that was recirculated back into the inlet of the turbo.

Since the maximum smoke level under steady-state is 15 percent opacity, this was used as the upper limit when setting the exhaust recirculation level. The goal was to achieve a 50 percent reduction in NO_x without exceeding the 15 percent smoke level or large loss in maximum power of the engine. The following lists the nominal percent EGR rates measured during a 13-mode smoke test.

Mode	Speed, rpm	Power, %	EGR Rate, %
1	700	0	47.2
2	1260	2	45.2
3	1260	25	31.3
4	1260	50	12.4
5	1260	75	10.4
6	1260	100	2.6
7	700	0	47.2
8	2100	100	6.5
9	2100	75	11.1
10	2100	50	18.6
11	2100	25	24.7
12	2100	2	41.6
13	700	0	47.2

The EGR rates were calculated from intake and exhaust CO_2 measurements by the following equation:

$$\% \text{ EGR} = \frac{\text{Intake } CO_2 - \text{Background } CO_2}{\text{Exhaust } CO_2} \times \frac{100 - \text{Intake } CO_2}{100 - \text{Exhaust } CO_2} \times 100\%$$

Note that at maximum power, modes 6 and 8, only a small EGR rate could be used while, at light loads and idle, rates were greater than 40 percent.

a. Smoke

Smoke was measured only at the 13-mode test conditions since the manual EGR system precluded transient operation. A comparison of the smoke results on Table 32 shows the gross increases in smoke when large amounts of hot exhaust gas were used instead of air in the intake charge to the engine. To obtain a 50 percent decrease in NO_x, an engine with typically low smoke levels was increased by a factor of 2.8.

b. Gaseous Emissions

The goal of "about half the standard engine NO_2" was almost met by application of the EGR to this engine. From Table 33, the 13-mode NO_2 was 7.3 versus 13.1 g/kw-hr. EGR doubled CO from 3.1 to 6.4 g/kw-hr and halved HC from 0.47 to 0.23. Brake specific fuel consumption was affected some, with an increase from 0.253 to 0.268 kg/kw-hr because of EGR. This is not to say that the application of EGR will invariably increase BSFC but only that some increase was expected because some exhaust was recirculated at all conditions, even maximum power. Maximum power at 2100 rpm was reduced from 248.8 to 232.8 kw and at 1260 rpm from 196.3 to 185.1 kw.

c. Particulate and Sulfate

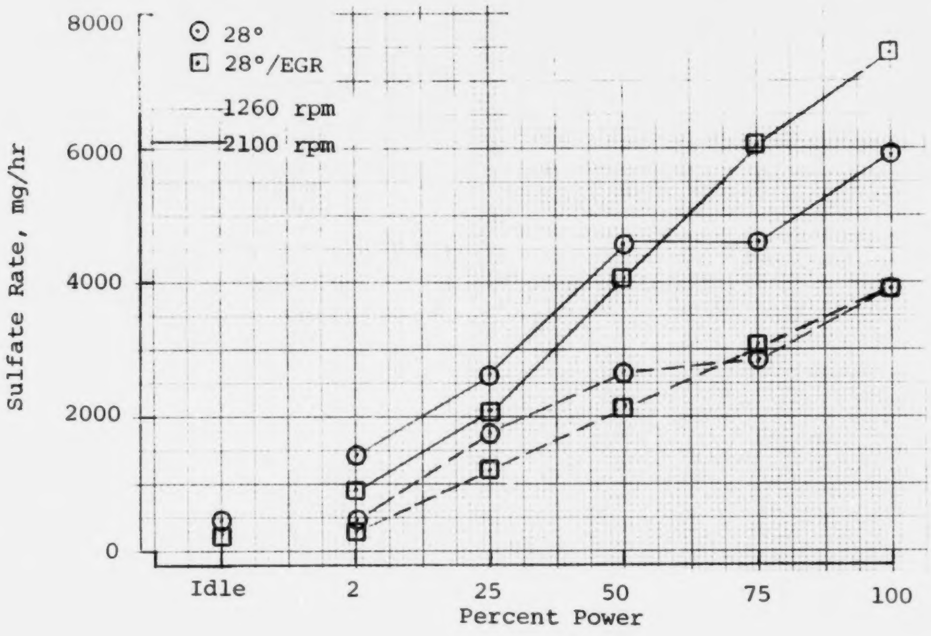
Table 34 indicated that EGR increased the particulate from 0.47 to 1.2 g/kw-hr, an increase of 2.7 times. Sulfate, however, appeared unaffected by EGR, with 28.5 mg/kw-hr standard engine versus 28.7 mg/kw-hr for the standard engine plus EGR. Thus, the particulate increase was likely due to increased carbonaceous or hydrocarbon-like matter rather than sulfate.

Figure 29 contains plots of particulate and sulfate mass rates by speed and load condition. Although EGR resulted in more particulate at maximum (100 percent) power, the greatest percent increase in particulate occurred at 75 percent of power. This and the other part-load conditions (25 and 50 percent) resulted in nearly threefold increase in particulate rates.

Sulfate behavior was a bit curious in that, between 50 and 75 percent power, the effect of EGR was to produce more sulfate. This was most pronounced at 2100 rpm on Figure 6. Below the crossover point, less than 50-75 percent power, EGR produced less sulfate. In most cases, the differences were not large and apparently self-compensated when calculated as a composite 13-mode rate.

Tables D-19 and D-24 list the sulfate emission rates for the standard DI Caterpillar 3406 and the EGR versions of the engine. The average fuel sulfur conversion to sulfur as sulfate was 1.86 percent with a range of 1.32 to 4.13 percent in the standard 28-degree timing version. The 4.13 percent was computed at idle. The conversion to sulfate was an average 1.45 percent, range of 0.84 to 1.91 percent, for the EGR configuration.

Figure 30 is an attempt to see if there is a relationship between visible smoke and particulate mass rate. The eleven different modes of the 13-mode test are the basis for comparison. Although the standard engine values might have some relationship to each other, it is evident that



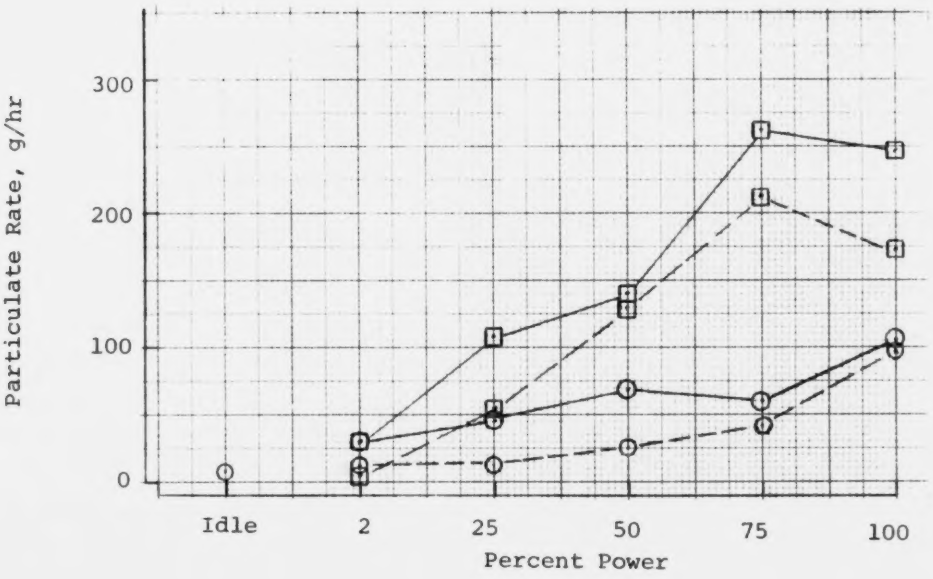


Figure 29. Particulate and Sulfate Modal Rates for Caterpillar 3406 DI With and Without EGR

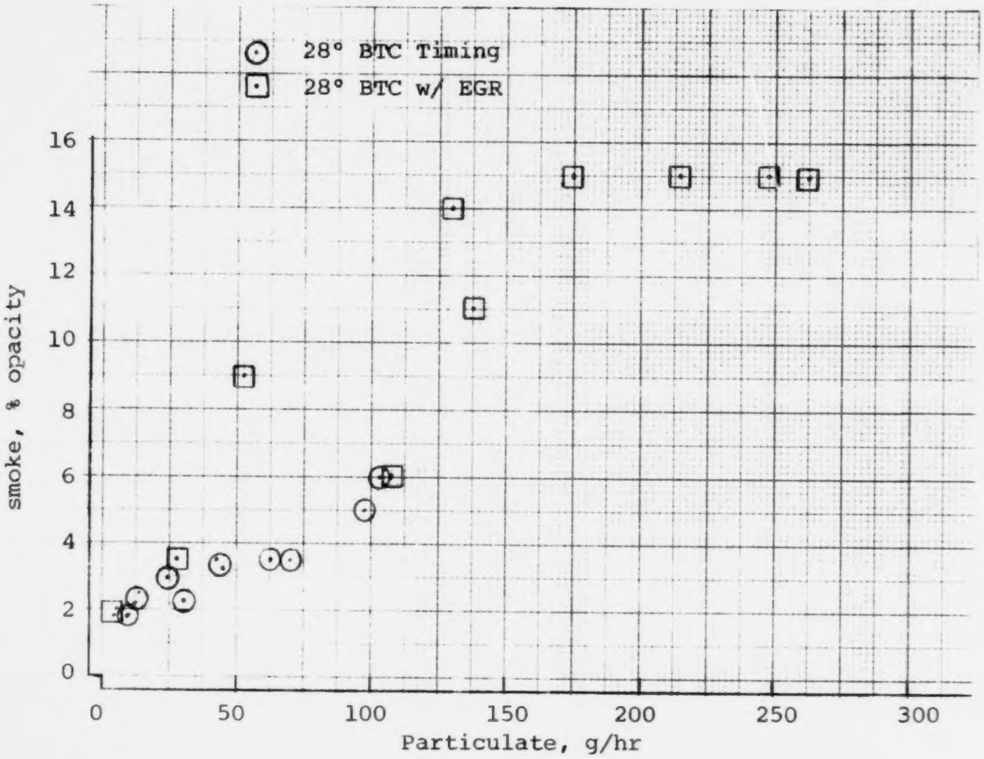


Figure 30. Modal Smoke and Particulate, Caterpillar 3406 DI With and Without EGR

with EGR there is no correlation. For example, particulate can range from 175 to about 275 g/hr, yet the smoke was the same, 15 percent opacity.

d. BaP and Organic Soluble Fraction

The following is a comparison of the BaP and organic soluble fraction based on the 7-mode test using weighting factors derived from the 13-mode FTP.

Configuration	Cycle Composite BaP, µg/kw-hr	Cycle Composite Org. Sol., %
DI, Standard Timing	0.20	17.9
DI, Standard Timing + EGR	0.11	19.5

From this comparison, BaP was about half that of the standard Caterpillar 3406 when operated with a substantial level of EGR. Organic solubles seemed little affected and again denote little relationship between BaP and the amount of organic solubles in the particulate.

e. Hydrogen, Carbon and Metal Content

The following compares the H/C mole ratio of the particulate matter:

Configuration	H/C Mole Ratio Max.	Min.	Avg.
DI, Standard Timing	1.64	0.13	0.80
DI, Standard Timing + EGR	1.33	0.10	0.52

As with retarded timing, discussed earlier, EGR resulted in a large increase in particulate. The above indicates that the content of the particulate shifted substantially to greater carbonaceous matter relative to the hydrogen content.

To illustrate the effect of EGR on the H/C ratio, the following is helpful.

Condition Speed/% Power	Standard Engine H/C Ratio	Standard Engine + EGR H/C Ratio	Standard Engine + EGR EGR, %
1260/2	1.44	1.13	45.2
1260/50	0.55	0.10	12.4
1260/100	0.13	0.12	2.6
Idle	1.25	1.33	47.2
2100/100	0.24	0.12	6.5
2100/50	0.35	0.20	18.6
2100/2	1.64	0.61	41.6

Note the influence of EGR on decreasing H/C ratio through a shift in higher C relative to H content. For example, 6.5 percent EGR at 2100 rpm/100 percent load resulted in half the H/C ratio. Apparently particulate H/C ratio is quite sensitive to EGR rate. Metals found on the 47 mm Fluoropore filter particulate are listed and compared on Table D-48 and show no obvious effect of EGR.

f. Particulate Sizing

The average of the 7-mode sizing data for EGR was plotted on Figure 27, discussed earlier. When using EGR, it appears that the average size distribution line shifted to the right on Figure 27, meaning the particles with EGR were even smaller than from the standard engine. The following compares the two configurations.

Particle Diameter ECD Microns	Cumulative Percent Smaller than ECD	
	Standard Engine	EGR
less than 10	99.3	99.7
5	98.5	99.4
2	94.8	96.7
1	92.0	94.4
0.5	86.5	89.3
0.42	84.6	87.3

This is an interesting observation that EGR, like retarded timing, results in finer particles. The effects are negligible from the standpoint that only 15 percent of the particulate is known to be thus affected.

g. DOAS

TIA is plotted as a function of power output on Figure 31. Generally, the highest TIA values were obtained at light load and idle with mixed behavior or no change between 50 and 100 percent power. TIA values from the exhaust gas recirculated engine were lower at all conditions except the 2-percent 2100-rpm condition.

To summarize this finding, the maximum, minimum and average LCO and TIA are listed next.

Configuration	LCO µg/litre			TIA
	Max.	Min.	Avg.	Avg.
DI, Standard Timing	17.2	4.5	9.8	2.0
DI, Standard Timing + EGR	11.9	1.2	5.2	1.7

It is apparent that DOAS results, TIA and LCO, were lower both in range as well as average value for the EGR-equipped engine. The average values are slightly lower than the 10-degree retarded timing LCO and TIA discussed earlier.

h. Aldehydes

Shown below is a summation of the individual aldehyde brake specific rates given earlier in Table 38.

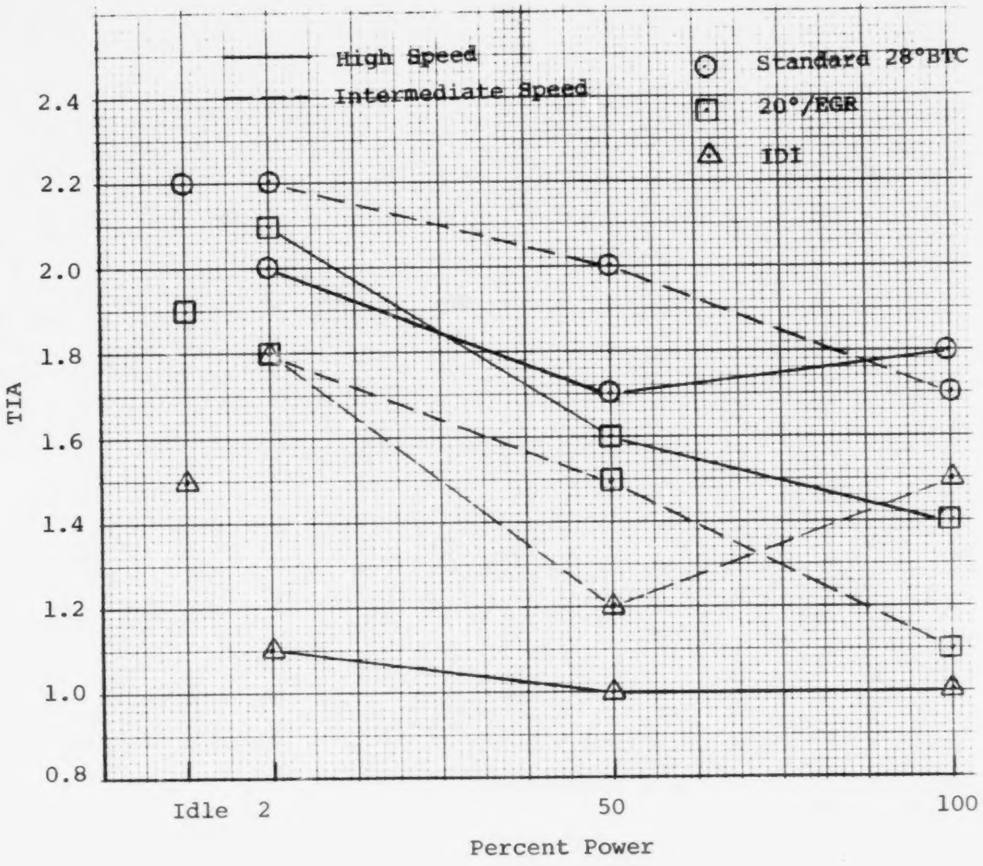


Figure 31. Effect of EGR on TIA Caterpillar 3406 DI Version

Configuration	Aldehydes µg/kw-hr	LCA, avg. µg/litre
DI, Standard Timing	97.9	12.8
DI, Standard Timing + EGR	107.0	6.1

Little difference is seen overall, and this is borne out by an examination of some individual aldehydes measured. Some were lower with EGR, such as formaldehyde, acetaldehyde and acetone, and some were higher, such as crotonaldehyde and hexanaldehyde.

Although aldehydes and LCA seemed to be related during the effect-of-timing discussion, such a connection seems remote when EGR was used. Aldehydes were little affected overall by the use of EGR, but LCA, by the DOAS, were halved per the above summary.

i. Specific Hydrocarbons

Compared to the standard engine, the sum of the eight hydrocarbons measured was lower with EGR (97 versus 124 mg/kw-hr). Less methane, ethylene, propylene and toluene were measured, while other HC were about the same. What mechanism is at work when exhaust is introduced into the engine to result in less of certain hydrocarbons is unknown. Table 39 and Tables D-55 and D-56 contain the detailed data for further study.

j. Summary

Like retarded timing, EGR as applied to the Caterpillar 3406 engine increased greatly the total mass of particulate emitted by the engine while decreasing NO_x. Smoke was increased, by intent, as a natural result of achieving a substantial, almost 50 percent, NO_x reduction. CO was doubled and HC halved. While particulate was increased by 2.7 times, sulfate appeared unaffected. BaP, with EGR, was cut in half, while organic soluble fraction was about the same. Particle size distribution with EGR shifted to indicate an even finer, lighter material than the same engine run in standard configuration.

3. Effect of Combustion Chamber

The selection of the Caterpillar 3406 engine for this entire series of experiments, timing and EGR, was because this is the only production HDD engine offered in both a direct injection and an indirect injection version. The indirect injection combustion chamber involves a prechamber, whereas the direct injection version uses an "open" type combustion chamber. It has long been known that a prechamber engine has inherently low NO_x, and tests of an earlier Caterpillar engine(6) illustrated not only low NO_x but comparatively low smoke, HC, CO and odor as well.

The prechamber type engine, though universally used for smaller high-speed Diesels used in cars, has never been as popular for buses and trucks (HD applications) as the direct injection (DI) engine because of its increased fuel consumption (higher BSFC). Accordingly, with the exception of this one domestic model which has negligible sales, all engines in over-the-road HDD applications use some version of an open chamber with direct fuel injection.

The conversion of the Caterpillar 3406 from DI to IDI was accomplished under the guidance and help of Mr. Ken Claar from Caterpillar using parts furnished by Caterpillar for this purpose. The conversion was done on March 22-24, 1978, and included changing of pistons, injector assemblies, and the pump assembly. Following conversion, the engine started easily and generated rated power at both rated and intermediate speeds. A pinging noise was evident at light loads, but this was considered "normal" for this engine configuration by the Caterpillar representative.

After the recommended break-in procedure, the series of smoke tests and performance tests were performed. Then, during a 20-minute maximum-power run to verify particulate tunnel temperatures, the engine suddenly lost power and came to a stop. The engine was restarted but could not achieve rated power. An abnormal amount of smoke was coming from the blow-by vent. Following a step-by-step inspection at the direction of Caterpillar (via phone conversations), it was found that the No. 5 cylinder's oil jet tube had broken off. This oil jet tube is located in the vicinity of the crankshaft and directs a jet of oil to the underside of the piston (one oil jet per cylinder). Engine failure apparently occurred as a result of loss of cooling and lubrication to No. 5 cylinder assembly, causing the piston to score the liner. Piston metal deposits were apparent around the circumference of the liner and ran the length of stroke. It is assumed that failure occurred immediately after oil jet failure due to the lack of piston discoloration (no oil coking) and the relatively good condition of the bearings. A new piston, injector nozzle and liner were installed in cylinder No. 5. Following another break-in procedure, the reassembled engine pulled rated load. Smoke data taken prior to engine failure were verified and the test program resumed. At time of failure the engine had accumulated 12 hours in the IDI configuration.

a. Smoke

Referring back to Tables 31 and 32, the IDI engine produced slightly lower smoke on the Federal Transient Smoke Cycle, in terms of "a" and "b" factors, and somewhat lower smoke under steady-state conditions. For example, the smoke at 2100 rpm at 100, 75, 50 and 25 percent power was less, as was smoke at 50, 25 and 2 percent, 1400 rpm. The smoke levels are all very low and the differences normally considered negligible. Only maximum power at 1400 rpm produced enough smoke to be even faintly visible to the human eye. Thus, this data can only be considered useful in a directional sense.

b. Gaseous Emissions

The following is a brief comparison of the 13-mode emissions and BSFC.

	g/kw-hr			BSFC
Combustion System	CO	HC	NO_2	kg/kw-hr
DI, Open Chamber	3.13	0.47	13.09	0.253
IDI, Prechamber	1.68	0.16	6.88	0.272

True to form, the IDI (prechamber) version reduced emissions of CO by half, HC to one-third, and NO_2 by half while increasing cycle BSFC by 7.5 percent relative to the DI version. Incidentally, the emissions and BSFC compared very favorably to engine data provided by Caterpillar on a similar engine. Two differences between the engine's speed are that the IDI engine idle speed is 600 instead of 700 rpm for the DI and the intermediate engine speed was 1400 instead of 1260 rpm. Both versions of the engine were run with identical preset restrictions, 76.2 cm (30-inch) water inlet and 68.6 mm (27-inch) water exhaust at rated speed and load.

c. Particulates and Sulfates

Figure 32 illustrates the modal behavior of the two combustion systems evaluated on the Caterpillar 3406 engine. The IDI or prechamber engine, at 2100 rpm, acted quite differently from the DI engine, with lower particulate at each power point. Instead of particulate mg/hr increasing rapidly between 75 and 100 percent power, as is usual and was found with the DI version, particulate was about the same as the 75 percent power point.

At intermediate speed, 1260 rpm for the DI and 1400 rpm for the IDI, the two combustion systems had almost identical particulate mass rate behavior. The IDI was slightly higher at 100 percent and somewhat higher at 75 percent power, but the difference in engine speed could account for this.

The brake specific particulate rates, given earlier on Table 34, allow for a direct comparison as follows.

Combustion System	Particulate g/kw-hr	Sulfate mg/kw-hr
DI, Open Chamber	0.47	28.5
IDI, Prechamber	0.37	41.0

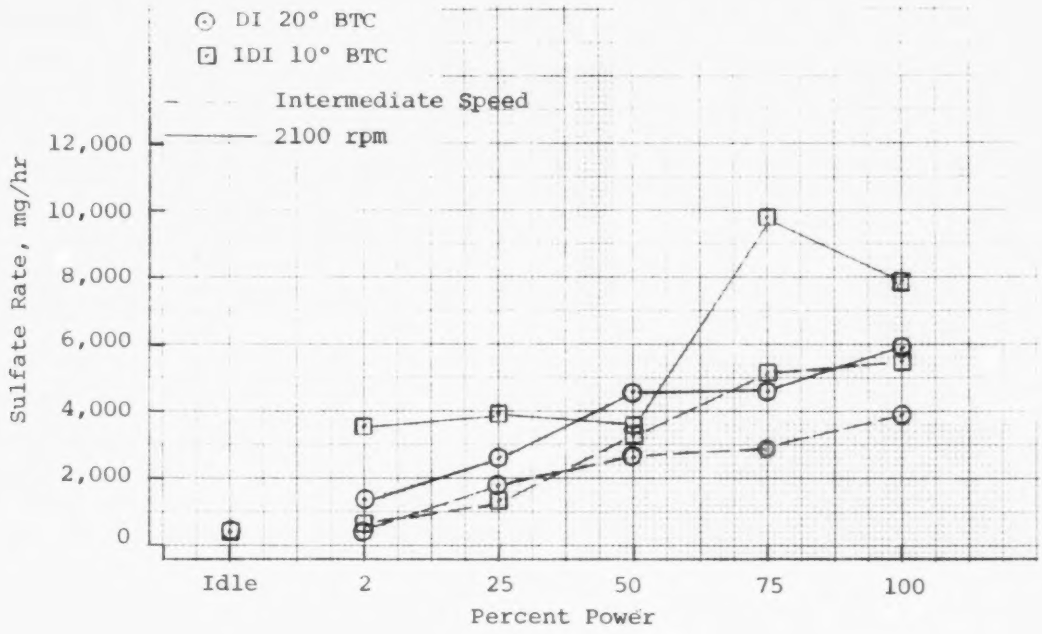
Approximately 20 percent reduction in particulate, from 0.47 to 0.37 g/kw-hr, is not very encouraging for the use of a prechamber engine. More difference had been expected. One reason for lack of a bigger change may be because the DI version of this specific engine is already a fairly low particulate emitter.

Sulfate trends on Figure 32 show higher mass emissions than the open-chamber DI engine. At rated speed, the prechamber IDI engine was higher at each test point except the 50 percent power. Intermediate speed (1260 rpm DI and 1400 rpm IDI) gave higher sulfate at 50,75 and 100 percent of power, but this could have been due to the higher speed and fuel rate.

The previous comparison from brake specific data in Table 34 indicates the prechamber engine to produce on the order of 40 percent more sulfate than the open-chamber engine. This is the only finding of significance so far in terms of engine effects on sulfate and is noteworthy.

From Table D-39, the sulfate conversion can be summarized as follows.

	Fuel S measured as $SO_4^=$, %		
Combustion System	Max.	Min.	Avg.
DI, Open Chamber	4.13	1.22	1.86
IDI, Prechamber	4.78	1.25	2.18



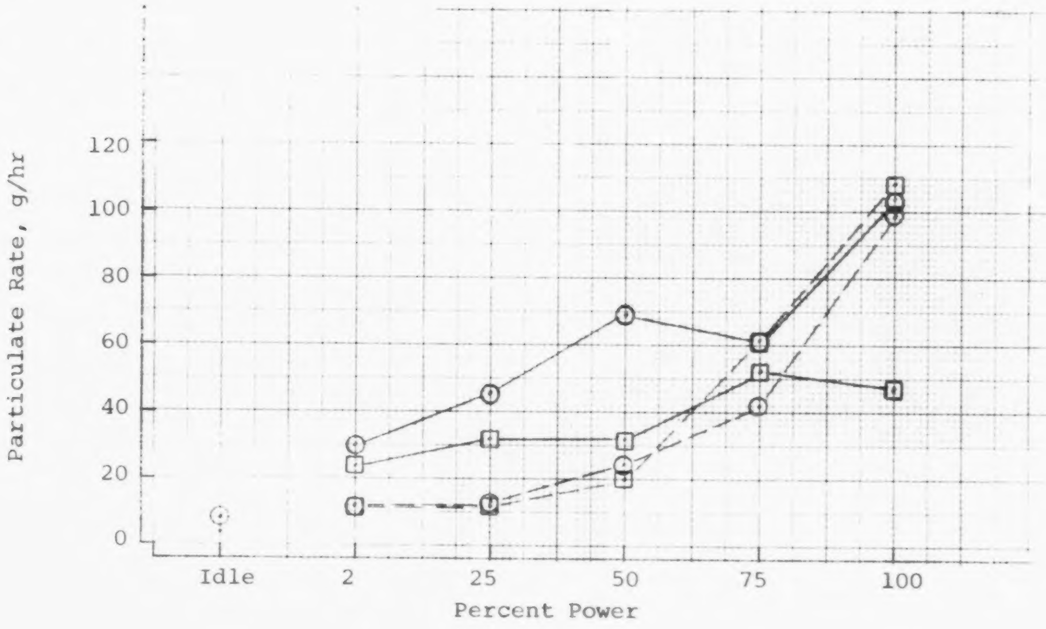


Figure 32. Particulate and Sulfate Modal Rates for Caterpillar 3406 DI Open Chamber and IDI Prechamber

On the average, this is a 17 percent increase in fuel sulfur conversion. However, the IDI engine uses slightly more fuel and some modes had a substantial 2.91 percent conversion, such as 2100-rpm 75-percent power

d. BaP and Organic Solubles

The following is a brief comparison of the IDI to the DI version of the Caterpillar 3406 engines' BaP and organic solubles on a 7-mode cycle composite.

	Cycle Composite	
Combustion System	BaP, µg/kw-hr	Org. Sol., %
DI, Open Chamber	0.20	17.9
IDI, Prechamber	0.14	11.1

In keeping with the lower overall particulate values with the IDI version, BaP and organic solubles were likewise lower. A 30 percent reduction in BaP and a 38 percent reduction in organic solubles are generally in line with the 20 percent reduction in particulate discussed earlier. Appendix Table D-47 contains the cycle composite calculations for further analysis.

e. Hydrogen, Carbon and Metal Content

The H and C elemental analyses for the IDI and DI versions of the Caterpillar 3406 are listed on Table 36 for each mode. Taking the average H/C mole ratio, little overall difference is seen in the two configurations as summarized below.

	H/C Mole Ratio		
Combustion System	Max.	Min.	Average
DI, Open Chamber	1.64	0.13	0.8
IDI, Prechamber	0.94	0.20	0.6

The range of H/C ratios was reduced by the IDI engine, and these data suggest a drier particulate with less organics by the IDI engine. From Table 36, H was the same or less on five of the seven conditions and C was higher on four of the seven conditions with the IDI engine.

A review of the sulfur and metals found on the filter showed little consistent difference between DI and IDI configurations. Sulfur content on the IDI filters was consistently twice the DI engine at all power levels at rated engine speed. Except at the 2 percent power, phosphorus and calcium were also higher. For more details, refer to Table D-48.

f. Particle Sizing

The results of the particle sizing experiments, when averaged for the seven test modes, coincide with the 5-degree advance timing and are very close to the standard timing direct injection engine. Thus, the particle size distribution may be viewed from Figure 27 using the dotted line for 5-degree advanced timing.

In short, the prechamber had no effect on particle sizing as measured by the Anderson impactor method. As with other configuration, little is known about the 85 percent of the particulate mass collected on the backup filter. The modal distributions are plotted in Figure D-5 for further examination.

g. DOAS

Plotted on Figure 31 are the TIA values measured with the IDI prechamber version of the Caterpillar 3406 engine. Compared to the direct injection engine, the IDI engine had substantially lower TIA values under every test condition. As with the DI engine, the TIA values were less at the intermediate speed (1260 rpm for DI and 1400 rpm for the IDI) than at 2100 rpm rated speed.

Combining the 7-mode DOAS values from Table 37, the following comparison can be made.

	LCO, μg/litre			TIA
Combustion System	Max.	Min.	Avg.	Avg.
DI, Open Chamber	17.2	4.5	9.8	2.0
IDI, Prechamber	6.8	1.0	2.6	1.4

Note that the overall average LCO and TIA values are substantially less from the prechamber engine. This is significant and is in qualitative agreement with a Caterpillar 1604 prechamber engine evaluated many years earlier.

h. Aldehydes

The summation of the seven individual aldehyde brake specific emission rates, listed on Table 38, is used to compare the IDI to the DI configuration.

Combustion System	Aldehydes mg/kw-hr	LCA, avg. μg/litre
DI, Open Chamber	86.9	12.8
IDI, Prechamber	106.9	3.6

The situation here is very similar to the EGR comparison, namely, little change in aldehydes as a total yet a large decrease in LCA by the DOAS. Individual aldehydes, such as formaldehyde, isobutyraldehyde and crotonaldehyde, were lower from the IDI version while acetaldehyde and benzaldehyde were higher.

i. Specific Hydrocarbons

Compared to the standard DI engine, the sum of the eight specific hydrocarbons, listed on Table 39, was about half with the prechamber IDI engine (68 versus 124 mg/kw-hr). Except for toluene, which was higher, each of the other hydrocarbons measured was about half that of the DI engine. This reduction in gaseous, low-molecular-weight hydrocarbons agrees qualitatively with the lower LCO and LCA via the DOAS and the lower 13-mode FTP hydrocarbon rate.

j. Summary

The prechamber indirect injection version of the Caterpillar 3406 engine tested resulted in about a 20 percent reduction in exhaust particulate, a 30 percent reduction in BaP and organic solubles, lower visible smoke, and about a 40 percent increase in sulfate. The increase in sulfate is noteworthy in that this is the only such occurrence found in all experiments with the Caterpillar 3406.

CO and NO_2 were halved, and substantial reductions in 13-mode FTP HC, LCA and LCO by the DOAS, and specific low-molecular-weight hydrocarbons were noted compared to the standard DI engine. A 7.5 percent increase in brake specific fuel consumption was found with the prechamber engine, however. In all, the results of this experiment were all directionally correct to previous experience.

B. Effect of Turbocharging

There is no way to evaluate the effect of a turbocharger alone on engine operation or its emission characteristics. Invariably, the addition of a turbocharger entails the modification of other essential items or adjustments of the once naturally aspirated engine in order that the resulting engine function satisfactorily.

Turbocharging in the minimum involves a change in injection pump recalibration and timing adjustments, as was the case for the Cummins NHC-250 engine tests in 1973.(13) Unlike the Cummins turbocharger retrofit kit, most installations involve a change in pistons and compression ratio as well as a number of lesser but just as important engine changes. Thus, any such comparison must be made with a turbocharged-equipped engine that has inherently certain changes which in themselves have effects on emissions, even if the turbocharger was not used.

For purposes of this study, Daimler-Benz OM-352 naturally aspirated and OM-352A turbocharged (TC) engines were selected. Both engines were described in detail in Section III of this report and are shown in Figure 1 ready for test. Although both are considered small six-cylinder Diesels that would be used in midrange applications, they were thought to be satisfactory selections to indicate the gross differences in particulate and sulfate from a pair of engines that are quite comparable except for turbocharging. Also, neither engine had ever been characterized in the EPA's Long Range Diesel Emissions Program.

1. Smoke

Table 40 lists the Federal Transient Smoke Cycle results for both engines. As is usual with turbocharged Diesels, the "b" factor, or maximum power "lug-down" part of the cycle, is much lower than the naturally aspirated Diesel engine. In this case, the "b" factor was less than half, 4.1 for TC versus 10.9 percent opacity for the NA engine.

Incidentally, the OM-352 compared reasonably well with the 10.6 and 11.3 percent "a" and "b" factors obtained at SwRI in March 1972. The OM-352A

TABLE 40. FEDERAL TRANSIENT SMOKE CYCLE OPACITY DAIMLER-BENZ OM-352 AND OM-352A

Engine Model	Run	Smoke Opacity, % "a"	"b"	"c"
OM-352	1	7.9	11.0	11.3
Naturally	2	7.9	10.8	11.2
Aspirated	Avg	7.9	10.9	11.2
OM-352A	1	7.9	4.2	14.2
Turbo-	2	7.0	3.9	11.6
Charged	Avg	7.5	4.1	12.9

125-hour "a", "b" and "c" factors measured in March 1974 were 12.5, 6.0 and 23.6 percent, respectively.

Table 41 lists the steady state smoke measurements in the 13-mode test and during a full-power test. Although part-load smoke levels are not much different at full power, the NA engine is much higher than the TC, and this is quite typical. Note the large difference in the opacity readings during the maximum-power test. The differences were greatest at high speed and diminished as the speed was decreased. The NA engine produced a constant 10-11 percent opacity, regardless of speed (2600 to 1600 rpm), while the TC engine smoke increased as speed decreased (2200 down to 1600 rpm).

2. Gaseous Emissions

Table 42 is a summary of the 21- and 13-mode tests for regulated gaseous emissions and BSFC. For more details, please refer to the computer printouts included as Tables D-60 through D-67 in Appendix D. Gaseous emission of HC+NO_2 was lower for the NA version due to the lower NO_2 emission from that configuration. HC emission from both configurations was almost the same, with the TC version just slightly lower. Also, the emission rate of CO was lower for the TC version. Fuel consumption for the TC configuration was lower by about 3.5 percent (0.284 versus 0.294 kg/kw-hr). Turbocharged engines typically have lower NO, as NO_2, and better brake specific fuel consumption. In regard to smoke, regulated emissions and BSFC, the differences are typical and expected. For the record, the 125-hour test of the OM-352A in March 1974 yielded 4.22 g/kw-hr CO, 2.49 g/kw-hr HC, 12.63 g/kw-hr NO_2, and HC+NO_2 of 15.12 g/kw-hr by the prescribed 13-mode test. These values agree very well with those reported on Table 42. Although this engine and the OM-352 engine had been in storage for some time, the smoke and gaseous emission values agree well with earlier data and validate the operating condition of the engines as used in this project.

3. Particulate and Sulfate

Table 43 lists the 13-mode composite particulate and sulfate results for both engines in brake and fuel specific units. The particulate rates for the naturally aspirated engine are almost twice the rates emitted by the TC

TABLE 41. STEADY-STATE SMOKE PERCENT OPACITY
DAIMLER-BENZ OM-352 AND OM-352A
13-MODE FTP STEADY-STATES

Mode	Engine Speed, rpm	Power, %	Smoke Opacity, % OM-352(NA)	Smoke Opacity, % OM-352A (TC)
1	600	---	0.1	0.2
2	2000	2	0.2	0.2
3	2000	25	0.4	0.3
4	2000	50	0.7	0.7
5	2000	75	1.4	2.2
6	2000	100	11.0	4.0
7	600	---	0.3	0.4
8	2800	100	9.7	3.1
9	2800	75	3.1	2.4
10	2800	50	1.8	1.0
11	2800	25	1.7	0.1
12	2800	2	1.3	0.1
13	600	---	0.2	0.2
		Maximum Power Smoke		
	2800		8.6	3.0
	2600		10.0	2.7
	2400		10.6	2.9
	2200		10.2	2.9
	2000		10.3	3.8
	1800		10.5	4.2
	1680		10.6	5.1
	1600		10.7	6.3

TABLE 42. GASEOUS EMISSIONS BY 21-MODE EPA AND 13-MODE FTP
DAIMLER-BENZ OM-352 AND OM-352A

Test	Run	Emission, g/kW-hr				Cycle BSFC kg/kW-hr
		CO	HC	NO_2[a]	HC + NO_2	
			Turbocharged			
21-EPA	1	4.809	3.080	11.963	15.043	0.289
	2	4.311	3.227	12.628	15.854	0.291
	Avg	4.560	3.154	12.296	15.449	0.290
13-FTP	1	4.413	2.940	11.877	14.816	0.284
	2	3.741	3.107	12.026	15.133	0.284
	Avg	4.077	3.024	11.952	14.975	0.284
			Natually Aspirated			
21-EPA	1	7.010	3.410	10.766	14.175	0.295
	2	6.510	3.446	10.369	13.815	0.298
	Avg	6.760	3.428	10.568	13.995	0.296
13-FTP	1	7.252	3.198	10.064	13.262	0.293
	2	6.740	3.210	9.903	13.112	0.294
	Avg	6.996	3.204	9.984	13.187	0.294

---

[a] NO_x as NO_2 by CL - 21-mode EPA
NO as NO_2 by NDIR - 13-mode FTP

TABLE 43. PARTICULATE AND SULFATE EMISSION RATES
(Based on 13-Mode Cycle)

		Brake Specific		Fuel Specific	
Daimler-Benz Configuration	Run No.	Particulate g/kW-hr	Sulfate mg/kW-hr	Particulate g/kg fuel	Sulfate mg/kg fuel
OM-352A	1	0.755	19.41	2.681	68.95
Turbocharged	2	0.753	17.91	2.686	63.87
	Avg.	0.754	18.66	2.684	66.41
OM-352	1	1.314	18.54	4.490	63.33
Naturally	2	1.341	19.53	4.590	66.86
Aspirated	Avg.	1.328	19.04	4.540	65.10

version. Sulfate rates from the NA version were essentially the same as the TC configuration.

Figure 33 is a plot of the particulate and sulfate mass rates for the various load and speed conditions evaluated. These plots make use of average rates contained in Tables D-68 and D-69 (OM-352A) and D-72 and D-73 (OM-352). Incidentally, Tables D-70 and D-71 and Tables D-74 and D-75 contain the 13-mode composite computations summarized in Table 44.

According to Figure 33, particulate rates from the OM-352 engine configuration were slightly higher than from the turbocharged configuration at low loads. At higher loads, particularly the 100 percent power modes, particulate rates were much higher than for the turbocharged version. Sulfate mass rates seemed to be fairly consistent, almost the same, except at the 75 and 100 percent, 1800 rpm points where the turbocharged engine produced higher sulfate rates than the naturally aspirated engine. Recall that the turbocharged engine intermediate speed is 1800 rpm and the naturally aspirated intermediate speed is 2000 rpm.

The percent of fuel sulfur conversion for the NA configuration ranged from 0.82 at 2000 rpm/100 percent to 2.61 percent at idle. Similarly, the fuel sulfur conversion for the TC configuration ranged from 0.68 to 3.04 percent at 1800 rpm/25 percent and idle, respectively. The OM-352A TC engine averaged 1.2 percent fuel sulfur-to-sulfate conversion, while the OM-352 NA engine conversion was 1.1 percent.

4. BaP and Organic Solubles

Table 44 lists the results of the seven modes evaluated for BaP and organic solubles using the 8 x 10 size filter. Particulate rates determined by this larger size fiberglass filter are also listed. Note that BaP was below minimum detectable at 100 percent power for both engines and engine speeds. BaP was lower for the TC engine at all other points except intermediate speed/2 percent power.

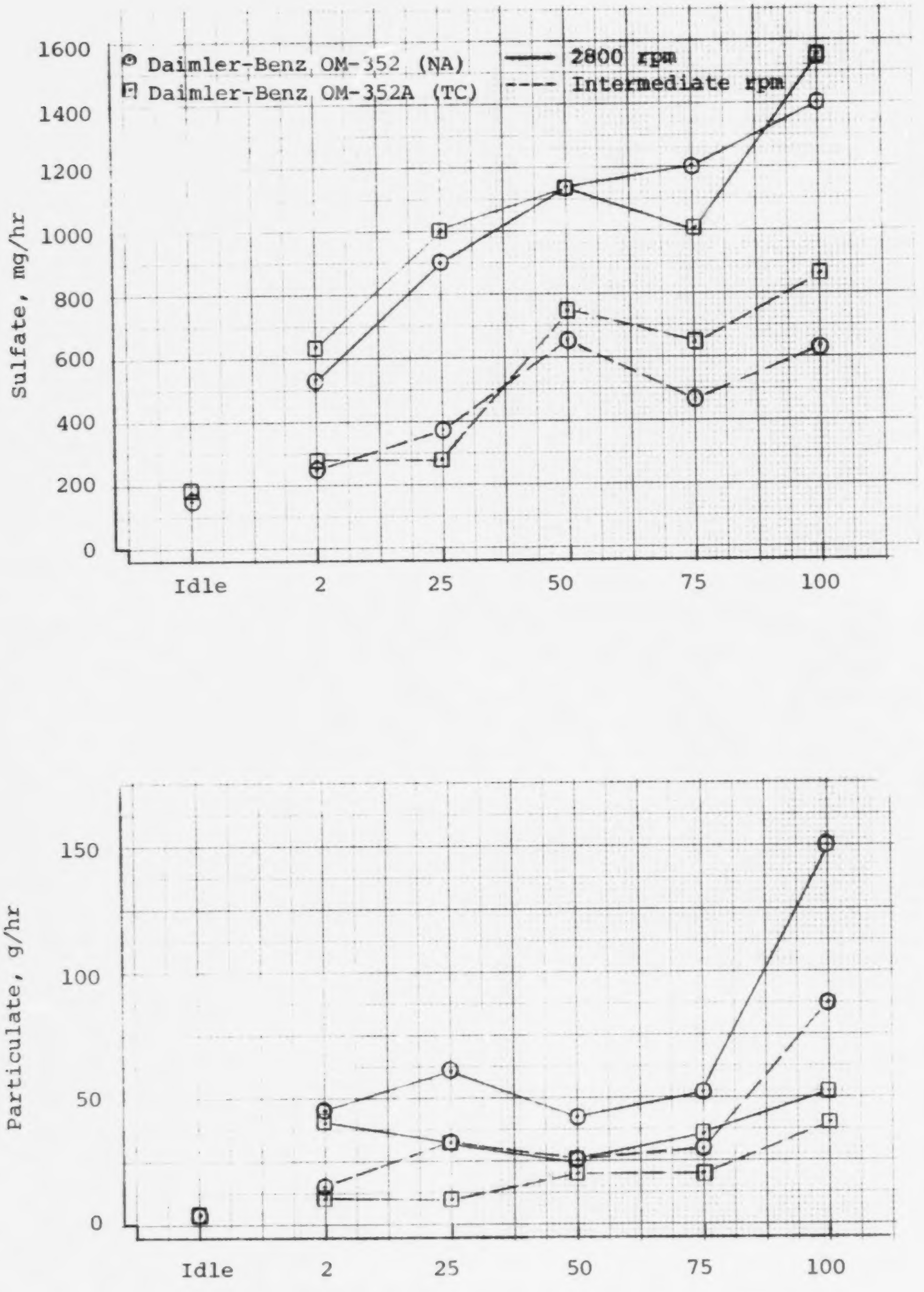


Figure 33. Particulate and Sulfate Modal Rates for Daimler-Benz OM-352 and OM-352A Diesel Engines

TABLE 44. SUMMARY OF PARTICULATE, BaP AND ORGANIC SOLUBLES
FROM 8 x 10 SIZE GLASS FILTER SAMPLES
DAIMLER-BENZ OM-352 AND OM-352A ENGINES

Condition rpm/load %	Engine Configuration	Particulate Rate				BaP				Organic Solubles, %
		mg/m^3	g/hr	g/kg fuel	g/kw-hr	µg/m^3	µg/hr	µg/kg fuel	µg/kw-hr	
1800/2	Turbocharged	44.54	11.81	4.07	9.08	0.075	19.86	6.85	15.28	28.86
2000/2	Naturally Aspirated	48.44	14.89	4.38	9.93	0.049	14.99	4.41	9.99	37.34
1800/50	Turbocharged	72.69	22.28	2.40	0.59	0.272	83.24	8.95	2.21	37.81
2000/50	Naturally Aspirated	96.12	29.77	3.31	0.83	0.179	55.49	6.17	1.55	57.24
1800/100	Turbocharged	104.41	39.36	2.34	0.54	BMD(1)	------	-----	-----	8.11
2000/100	Naturally Aspirated	322.58	99.54	5.56	1.40	BMD	------	-----	-----	7.13
Idle	Turbocharged	51.41	4.77	7.95	-----	0.352	32.62	54.37	-----	17.48
	Naturally Aspirated	74.15	6.84	8.55	-----	0.593	54.77	68.46	-----	17.07
2800/100	Turbocharged	95.77	59.76	2.26	0.56	BMD	------	-----	-----	7.70
	Naturally Aspirated	392.96	165.42	6.59	1.73	BMD	------	-----	-----	7.40
2800/50	Turbocharged	95.12	47.54	3.07	0.88	0.194	96.99	6.26	1.79	39.74
	Naturally Aspirated	108.63	45.32	3.26	0.89	0.289	120.71	8.68	2.38	51.59
2800/2	Turbocharged	110.08	44.82	7.35	21.34	0.106	43.01	3.36	20.48	66.36
	Naturally Aspirated	113.59	46.45	7.87	22.12	0.162	66.16	11.21	31.50	59.14

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(1) Below Minimum Detectable

The following lists the cycle brake specific BaP and organic soluble percentages for both engines.

Engine	Cycle Composite BaP, µg/kw-hr	Cycle Composite Org. Sol., %
OM-352 NA	1.43	34.2
OM-352A TC	1.17	29.2

The TC engine produced 18 percent less BaP and 15 percent less organic solubles in the particulate than the OM-352 engine. These differences were not as great as would be expected by the reduction in gross particulate through turbocharging, namely, 1.328 to 0.754 g/kw-hr, or 43 percent. Apparently, the turbocharged engine produced less carbonaceous type soot particulate while organics were less affected. For modal and other details leading to the cycle values, please refer to Tables D-76 and D-77.

5. Hydrogen, Carbon and Metal Content

The following is a comparison of the elemental analyses of the naturally aspirated OM-352 and turbocharged OM-352A Daimler-Benz engines.

Comparison of Carbon and Hydrogen
Content of Daimler-Benz OM-352 and OM-352A

Condition Speed/Load	Carbon 352	Carbon 352A	Hydrogen 352	Hydrogen 352A	H/C(2) 352	H/C(2) 352A
Inter(1) 2	59.09	62.09	8.49	8.95	1.71	1.72
	70.08	72.77	8.87	6.92	1.51	1.13
	85.10	73.93	1.20	1.17	0.17	0.19
	48.64	48.46	5.74	4.29	1.41	1.06
	87.58	70.26	1.09	4.61	0.15	0.78
	68.86	72.49	7.84	6.13	1.36	1.01
	70.79	70.11	10.13	8.98	1.71	1.53

---

(1) 2000 rpm for OM-352 NA and 1800 rpm for OM-352A TC
(2) Mole Ratio

Overall, there is essentially no change in either hydrogen, carbon or the H/C mole ratio between engine versions. The average H/C mole ratio was 1.15 for the naturally aspirated engine compared to a 1.06 average for the turbocharged engine.

Metals and sulfur analyses for both engines are listed on Table D-78. Phosphorus, sulfur and calcium were the most consistently found. The comparison was very inconsistent in that sometimes the NA engine would be lower, sometimes higher, and often the same or essentially the same. Quite a variety of metals were found compared to some engines.

6. Particle Sizing

The turbocharged OM-352A particle size distribution appears slightly finer and lighter than the naturally aspirated OM-352 according to the plots on Figure 34. These are simple averages of the 7-mode data given on Table D-79. For similar distribution plots of each speed/load condition, refer to Figures D-6 and D-7.

The particulate is, like the Caterpillar 3406 discussed earlier, very small, and the Anderson only classifies about 13 percent of the largest portion of the exhaust particulate. The following illustrates this.

Particle Diameter ECD, Microns	Cumulative Percent Smaller than ECD	
	OM-352 NA	OM-352A TC
less than 10	99.4	99.5
5	97.8	98.4
2	94.4	95.0
1	81.9	94.1
0.5	88.0	89.5
0.42	86.8	87.9

7. DOAS

Table 45 lists the DOAS results for the seven modes evaluated. The TIA values are plotted on Figure 35. For the naturally aspirated engine

TABLE 45. DOAS RESULTS FOR DAIMLER-BENZ ENGINES

		Intermediate(2) rpm			2800 rpm			
Engine	DOAS(1)	2	50	100	Idle	100	50	2
OM-352A TC	LCA	59.5	57.7	56.9	52.7	33.9	63.4	57.8
	LCO	22.7	16.0	23.7	20.3		24.0	18.2
	TIA	2.4	2.2	2.4	2.3	2.3	2.4	2.3
OM-352 NA	LCA	61.2	76.3	12.2	47.7	8.8	58.2	75.7
	LCO	22.6	20.1	6.7	12.6	3.4	21.5	27.8
	TIA	2.4	2.3	1.8	2.1	1.5	2.3	2.5

---

[a] LCA and LCO in μg/litre

[b] 1800 rpm OM-352A TC, 2000 rpm OM-352 NA

(OM-352) the TIA decreased as power level increased. The turbocharged engine (OM-352A) TIA values were relatively constant at all speeds and loads. To summarize, the following comparison is offered.

	LCO, μg/litre			TIA
Engine	Max.	Min.	Avg.	Avg.
OM-352 NA	27.8	3.4	16.4	2.2
OM-352A TC	24.0	16.0	20.9	2.32

Overall, the TIA values reveal little difference between the two engines.

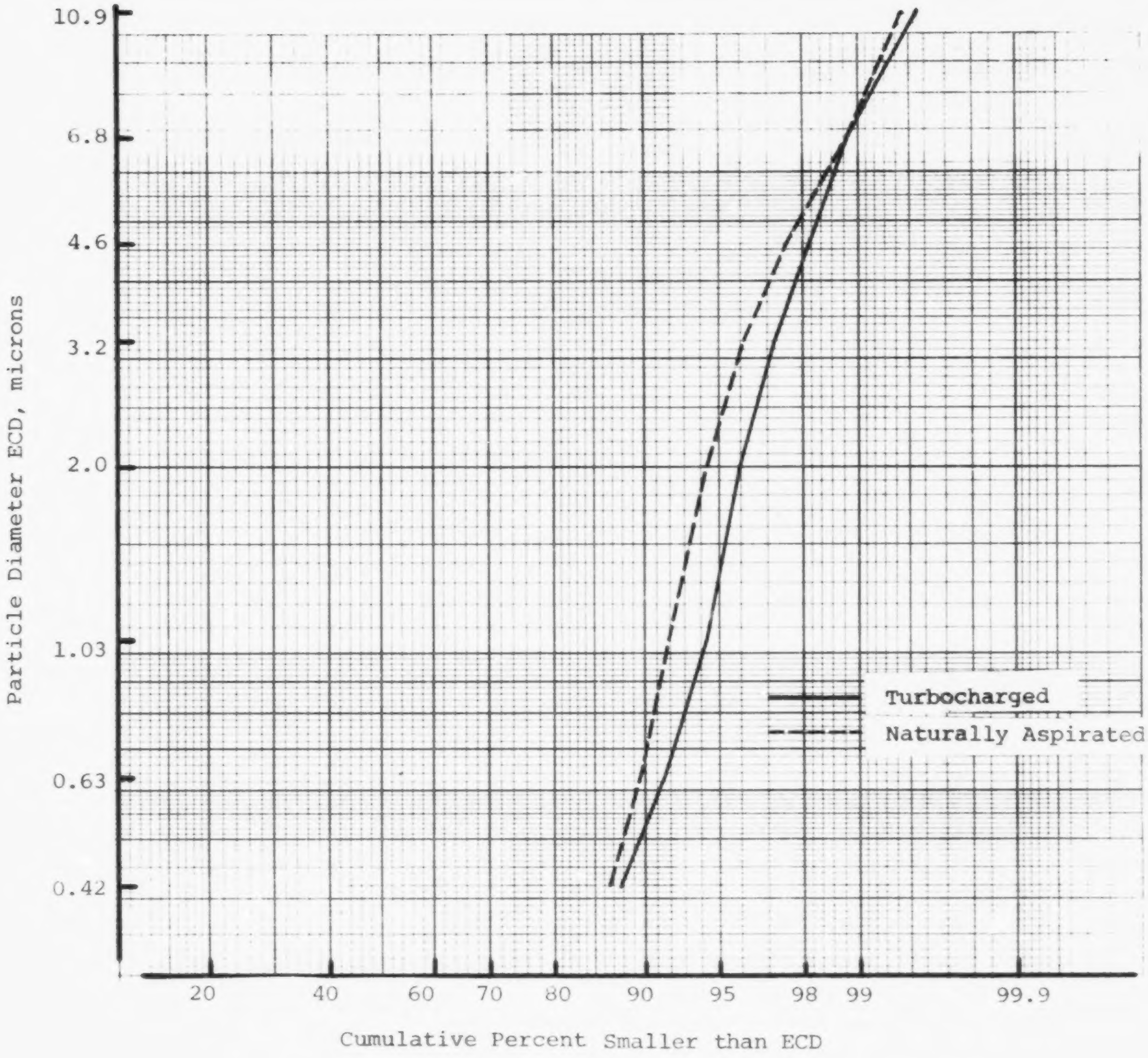


Figure 34. Particle Size Distributions by "Means" for Daimler-Benz OM-352, via Impactor

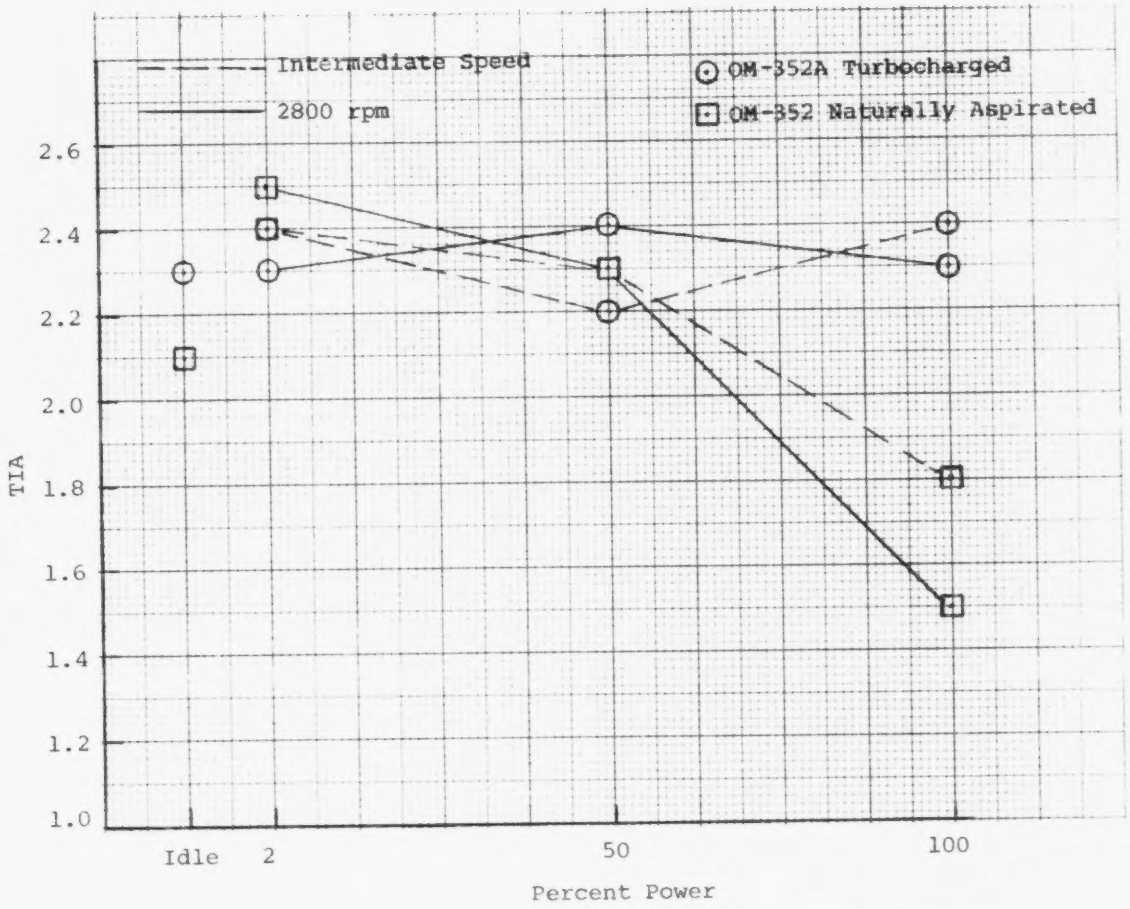


Figure 35. Effect of Turbocharging on TIA, Daimler-Benz OM-352A and OM-352 Engines

8. Aldehydes

For quick comparison, the combined brake specific aldehydes are listed below:

Engine	Aldehydes mg/km-hr	LCA µg/litre
OM-352 NA	375	48.6
OM-352A	372	54.6

Although the LCO and TIA and LCA (from above) were a bit lower with the naturally aspirated engine, the overall aldehyde values were unchanged.

Table 46 contains the seven individual aldehydes and indicates little significant difference in any of them due to the engine. Isobutyraldehyde was half the NA rate with the TC engine. For more details, please refer to Tables D-80 and D-81 which contain modal rates for both engines.

TABLE 46. BRAKE AND FUEL SPECIFIC ALDEHYDES RATES
DAIMLER-BENZ OM-352 NA AND OM-352A TC

	OM-352 NA		OM-352A TC	
Aldehyde	mg/kw-hr	mg/kg fuel	mg/kw-hr	mg/kg fuel
Formaldehyde	91.62	309.90	98.88	352.46
Acetaldehyde	48.49	164.02	56.25	200.50
Acetone	25.28	85.49	31.64	112.78
Isobutyraldehyde	21.65	73.24	11.55	41.17
Crotonaldehyde	34.72	117.42	36.32	129.47
Hexanaldehyde	25.63	86.68	29.19	104.03
Benzaldehyde	127.58	431.51	107.86	384.47
Total Aldehydes	374.97	1268.26	371.69	1324.88

9. Specific Hydrocarbons

Table 47 lists the eight specific hydrocarbons computed on a brake specific basis using a 7-mode test. In this case, the naturally aspirated engine produced less of certain low-molecular-weight hydrocarbons such as methane, ethylene, propylene and benzene. Even though the NA engine produced more methane, acetylene and propane, the combined specific hydrocarbons from the NA engine were lower than the TC engine (371 versus 437 mg/kw-hr). Further details for the seven modes are given in Tables D-82 and D-83.

10. Summary

Smoke and particulate were substantially less with the OM-352A turbocharged engine under the steady state conditions evaluated. Although particulate

TABLE 47. BRAKE AND FUEL SPECIFIC HYDROCARBON RATES
DAIMLER-BENZ OM-352 NA AND OM-352A TC

Hydrocarbon	OM-352 NA		OM-352A TC	
	mg/kw-hr	mg/kg fuel	mg/kw-hr	mg/kg fuel
Methane	29.65	99.99	23.31	83.09
Ethylene	217.10	734.28	260.17	927.37
Ethane	3.32	11.22	3.53	12.57
Acetylene	23.50	79.49	15.53	55.34
Propane	0.42	1.44	0.06	0.23
Propylene	66.77	225.84	100.98	359.95
Benzene	20.19	68.28	24.41	87.00
Toluene	9.96	33.69	8.74	31.16
Total Hydrocarbons	370.91	1254.23	436.73	1556.71

was about 40 percent less, essentially no change in sulfate was found. BaP was less by about 18 percent from the TC engine. The TC engine also had lower CO and HC and higher NO_2 with slightly better cycle BSFC (about 3 percent). This behavior was anticipated from previous experience of turbocharging Diesels. No effect on particle size distribution was found.

It is interesting to note that the TC engine resulted in slightly higher DOAS values of LCO, LCA and TIA as well as slightly higher combined low-molecular-weight HC, while the reverse was indicated by the 13-mode FTP HC value.

C. Effect of Injection System

At the February 1977 SAE Congress, American Bosch presented a paper(64) describing a new type of injection system utilizing a high-pressure pump to obtain much higher fuel injection pressures. A simple valve is used in the pump, designated the APS pump, to each of three plungers to distribute fuel alternatively to two cylinders of a six-cylinder truck size Diesel engine. These "shuttle" valves are moved hydraulically using the low-pressure fuel supplied by the transfer pump.

Injection pressures up to 172,000 kPa (25,000 psi) at the nozzle holder are reported to be obtainable with many possible wave pulse shapes possible. For example, a nearly "square" pulse pressure pattern has been achieved that is nearly flat at about 103,000 kPa (15,000 psi) nozzle pressure after the nozzle opens. Much more descriptive material may be obtained from Reference 64.

Conversations in early March 1977 with Mr. Jack Kimberley of American Bosch and subsequent discussions with Mr. Henry Doty (March 1977), Mr. Kimberley (November 1977), and finally Mr. Lou Yumlu of Mack Trucks and Mr. Kimberley (January 1978) led to the subsequent availability of the engine parts (Mack) and APS fuel injection system (American Bosch) for evaluation. Throughout the negotiations with Mack and American Bosch the Project Officer was kept informed of the experimental hardware status.

In conjunction with the Project Officer, American Bosch and Mack Trucks, a plan of test was devised that utilized the same Mack ETAY(B)673A engine characterized as part of Phase IA and discussed earlier in Section IV. For a description of this engine, please see Table 1 of Section III. The plan was to convert the engine to the high-pressure system and determine particulate, sulfate and the other emissions as with other engine effects already discussed in this section. Then a new standard Robert Bosch pump and set of injectors would be installed and particulate, sulfate and selected emissions measured. Thus, particulate results can be compared from three configurations, namely, (1) the standard engine with 1000 hours durability, (2) the same engine with high-pressure injection system, and (3) the same engine with new standard injection system.

Mr. Jack Kimberley and Mr. John Cavanaugh of American Bosch arrived on May 8, 1978, to supervise the engine conversion. Figure 36 illustrates the basic setup used to supply fuel to the injection pump at approximately 90 psi.

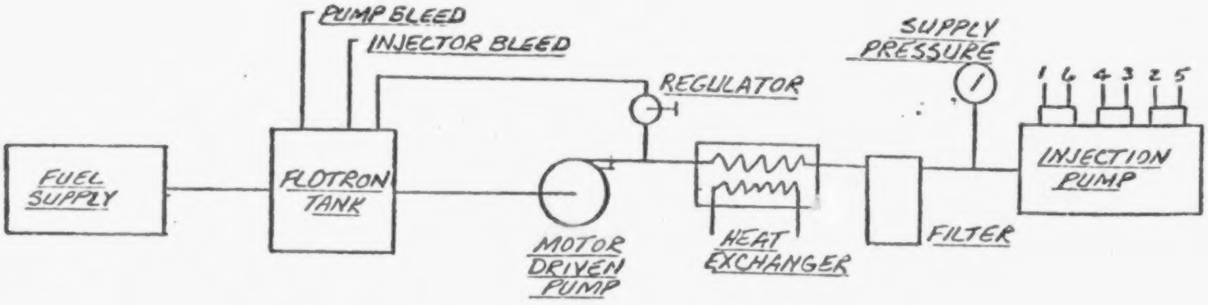
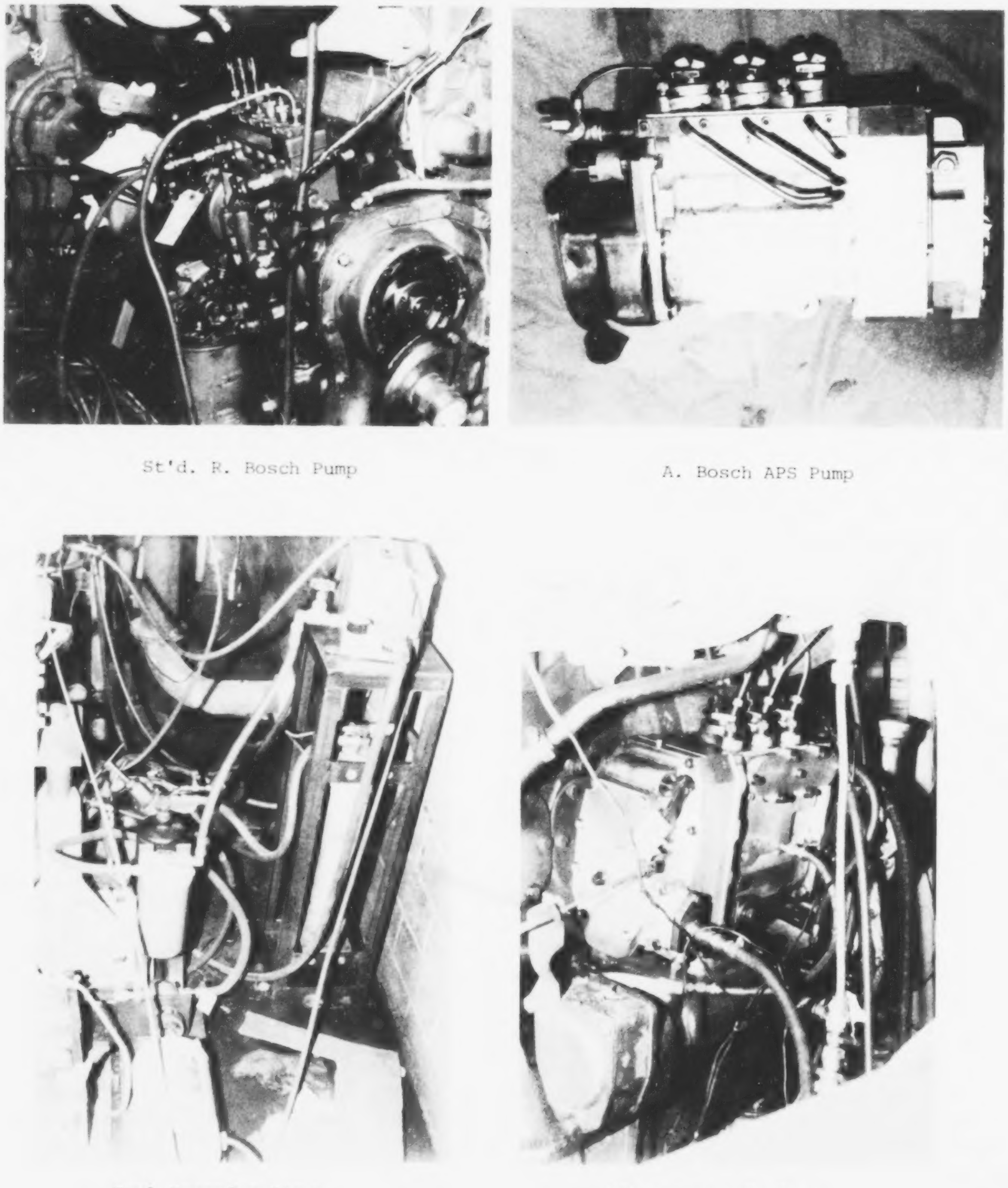


Figure 36. Simplified Schematic of APS Pump Setup

The experimental installation was successfully completed after several days of conversion, including installation of new timing gears in the engine to operate the pump at crankshaft speed, installation of the APS pump, new injectors and injection lines, as well as the items for fuel supply and delivery to the APS pump. Figure 37 shows these items as installed on and adjacent to the engine. A static injection timing of 10 degrees BTC was used, which is retarded from the normal 21-degree BTC basic timing of the standard R. Bosch pump.

Once the experimental system was installed, a series of preliminary engine tests was made to assure the system was operating properly and to the satisfaction of Mr. Kimberley and Mr. Cavanaugh. Preliminary smoke measurements and injection line pressure traces indicated that the engine was operating as expected. The experimental pump did not have internal governing and smoke-limiting mechanisms. Due to the absence of the governing system, the engine's maximum torque output at rated and intermediate speeds was manually limited by fuel flow representative of previous tests, 55.3 kg/hr



St'd. R. Bosch Pump

A. Bosch APS Pump

Fuel Transfer Items

APS Pump on Engine

Figure 37. American Bosch APS Pump Installed on Mack ETAY(B)673A

(122 lb/hr) at 1900 rpm/100 percent load and 50 kg/hr (108 lb/hr) at 1450 rpm/100 percent load. In addition, idle and intermediate speed/2 percent modes required that the fuel supply pressure be reduced to 69 kPa (10 psi) and 414 kPa (60 psi), respectively. This was done to minimize engine speed hunting. The lack of a speed governor prevented operating the engine under the Federal Transient Smoke Test. Figure 38 contains three injection pressure-time or crank angle photographs. Each photo was of a different speed as described in Table 48. Also listed are the measured opening and peak injection pressures.

TABLE 48. MACK ETAY(B)673A WITH HIGH-PRESSURE INJECTION SYSTEM

Photo No.	rpm/ Power	kPa/ cm	(Time base) deg/cm	Opening Press., kPa	Peak Press., kPa	Start of Injection	Fuel Supply Press., kPa
1	700/ No Load	13,790 (2,000)	4.2	23,443 (3,400)	27,580 (4,000)	6.3°BTDC	69 (10)
2	1450/ 100%	27,580 (4,000)	8.7	68,950 (10,000)	104,804 (15,200)	1.74°BTDC	621 (90)
3	1900/ 100%	27,580 (4,000)	5.7	91,014 (13,200)	132,384 (19,200)	1.14°ATDC	621 (90)

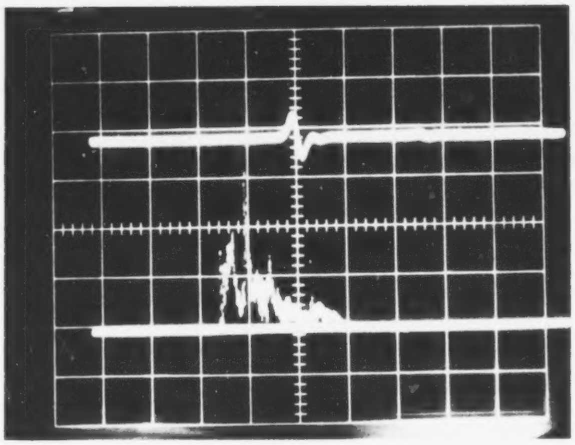
Values in parenthesis are in psig

The major problems encountered with the system were repeated injection line failure and difficulty in running the low or curb idle mode. After two hours of intermittent operation, an injector line cracked next to the injector nozzle. Shortly after replacement of this line, another injector line cracked at a similar location. After this second repair, the injection lines were supported in order to reduce vibration. This sort of failure was experienced on other fuel lines, and they were replaced each time by stainless steel injection lines furnished by American Bosch. The low idle condition engine instability was reduced, but not eliminated, by the reduced supply pressure. This did not prevent testing at idle, although the engine speed wandered about somewhat.

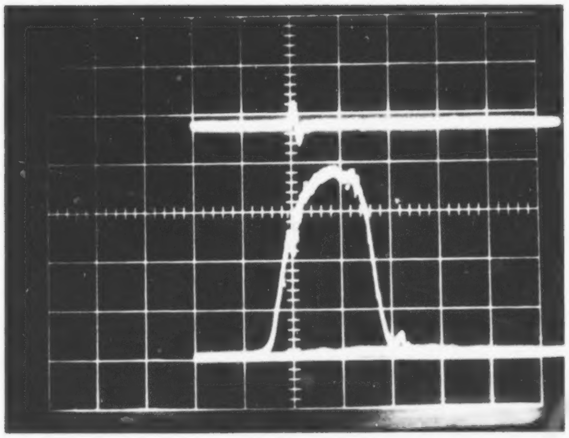
1. Smoke

Although the Federal Transient Smoke Test could not be run with the ungoverned APS pump system, modal smoke (13-mode) and a full-power curve smoke reading under steady state were obtained. They are listed in Table 49 along with the 1000-hour engine full-power results from Section IV. Since particulate rates and gaseous emission results were quite similar for the standard engine with 1000-hour pump and the new Robert Bosch pump, no additional smoke tests were run with the new Robert Bosch pump.

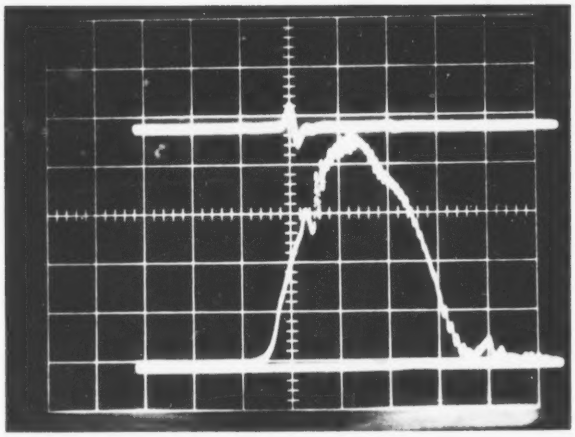
The modal smoke values were all very low, with 2.1 percent maximum recorded at 1450 rpm maximum power. The comparison to the 1000-hour standard



1. 700 rpm, 2000 psi/cm, (Time base) Deg/cm 4.2, opening press. (psi) 3400



1450 (Max) rpm, 4000 psi/cm, (Time base) Deg/cm 8.7, opening press. (psi) 10,000



3. 1900 (Max) rpm, 4000 psi/cm, (Time base) Deg/cm 5.7, opening press. (psi) 13,200

Figure 38. Injection Pressure Photos for Mack ETAY(B)673A Diesel with A. Bosch APS High-Pressure Injection System

TABLE 49. STEADY-STATE SMOKE PERCENT OPACITY MACK ETAY(B)673A WITH APS PUMP

13-MODE FTP STEADY-STATES

Mode	Engine Speed, rpm	Power %	Smoke Opacity %
1	650	---	0
2	1450	2	0.1
3	1450	25	0.5
4	1450	50	1.0
5	1450	75	1.9
6	1450	100	2.1
7	650	---	0.2
8	1900	100	1.4
9	1900	75	0.8
10	1900	50	0.7
11	1900	25	0.4
12	1900	2	0.3
13	650	---	0.1

MAXIMUM POWER SMOKE, %

rpm	APS High Pressure System	Standard Engine 1000 hr pump
1900	1.2	5.9
1700	1.4	7.6
1500	2.2	10.5
1450	3.2	11.6
1300	6.2	19.1

engine is quite dramatic, as shown by the full-power smoke values at the bottom of Table 49. With the APS system, exhaust smoke was about one-fourth that of the standard engine. To the extent full-power smoke can be used to predict particulate, a substantial reduction in particulate might be indicated.

2. Gaseous Emissions

The 21- and 13-mode gaseous emission composite values are listed in Table 50 for the APS-equipped engine. The standard 1000-hour engine average results from Section IV are listed for comparison. Similar tests for the new Robert Bosch pump were not performed. $HC+NO_2$ by either test procedure was higher with the APS pump. NO_2 was higher by about 45 percent. Normally, retarding static injection reduces NO_2 and increases smoke and particulate, all other factors being equal.

However, the experimental high-pressure pump is completely different so that the change in injection timing, a necessary requirement for the APS pump to operate, cannot be directly related to NO_2 or particulate by itself. A more extensive test plan could have included several APS configurations, producing a range of $HC+NO_2$. The limited scope of this project did not permit such an evaluation. Consequently, the configuration, i.e., pressure-time characteristic and timing, that was thought to have the greatest benefit on particulate was selected by American Bosch at SwRI request.

It is interesting that the APS pump slightly decreased CO and slightly increased HC from the 1000-hour baseline. Of major importance is the small but positive 4-percent improvement (reduction) in brake specific fuel consumption. This effect with the APS pump was somewhat unexpected since this engine already has a very respectable cycle BSFC. For additional modal results, please refer to Appendix Tables D-84 through D-87, the computer printout sheets for the APS experiments.

3. Particulate and Sulfate

A comparison of the particulate and sulfate 13-mode cycle composite emission rates is listed on Table 51. Although sulfate was little affected by the various injection systems, i.e., high pressure versus either old 1000-hour pump or new standard pump, a major reduction in particulate was found. The following indicates a 51 to 55 percent reduction in brake specific particulate, depending on whether the old or new standard injection system is used as reference.

$$\text{APS vs 1000-hour pump} \qquad \frac{0.821 - 0.399}{0.821} \times 100\% = 51\%$$

$$\text{APS vs new standard pump} \qquad \frac{0.896 - 0.399}{0.896} \times 100\% = 55\%$$

$$\begin{array}{l}\text{APS vs average of 1000-hour} \\ \quad \text{and standard pump}\end{array} \qquad \frac{0.859 - 0.399}{0.859} \times 100\% = 53\%$$

Confirmation of the APS improvement is afforded by the two separate experiments with the standard engine operated with a 1000-hour pump and injector system and then, over one year later, with a new standard pump and injector system. The repeatability of the cycle brake specific particulate

TABLE 50. GASEOUS EMISSIONS BY 21-MODE EPA AND 13-MODE FTP MACK ETAY(B)673A WITH APS PUMP

Test	Run No.	Gaseous Emissions g/kw-hr CO	HC	NO_2[a]	$HC + NO_2$	Cycle BSFC kg/kw-hr
High-Pressure A. Bosch APS Configuration						
21 EPA	1	1.782	0.802	11.745	12.547	0.239
	2	1.733	0.763	11.574	12.337	0.239
	Avg	1.758	0.782	11.660	12.442	0.239
13 FTP	1	1.685	0.699	12.130	12.829	0.233
	2	1.671	0.677	11.997	12.674	0.234
	Avg	1.678	0.688	12.064	12.752	0.234
Standard R. Bosch Configuration, 1000-hour						
21 EPA		2.150	0.655	8.006	8.661	0.247
13 FTP		2.129	0.638	8.865	9.502	0.243

(a) NO_x as NO_2 by CL - 21-mode EPA
NO as NO_2 by NDIR - 13-mode FTP

TABLE 51. MACK ETAY(B)673A SULFATE AND PARTICULATE EMISSION RATES - APS PUMP CONFIGURATION (BASED ON 13-MODE CYCLE)

Engine Configuration	Run No.	Brake Specific Particulate g/kw-hr	Brake Specific Sulfate mg/kw-hr	Fuel Specific Particulate g/kg fuel	Fuel Specific Sulfate mg/kg fuel
High Pressure	1	0.398	42.73	1.722	184.86
A.Bosch Pump	2	0.400	42.82	1.725	184.50
10° BTC	Avg	0.399	42.78	1.724	184.68
Standard Pump	1	0.845	47.05	3.628	202.03
1000 hr	2	0.796	42.67	3.429	182.75
21° BTC	Avg	0.821	44.86	3.529	192.39
Standard Pump	1	0.886	47.34	3.698	197.50
New	2	0.906	50.22	3.782	209.48
21° BTC	Avg	0.896	48.78	3.740	203.49

with old and new standard pumps in considered quite satisfactory. It is interesting that the particulate from the 1000-hour pump and injectors was essentially no different from the new pump. This indicates a lack of deterioration in particulate rate with operation and is noteworthy.

Figure 39 is a plot of the eleven speed-load conditions in g/hr (particulate) and mg/hr (sulfate). There is essentially no difference in sulfate mass rate, as indicated earlier by the cycle specific values. Particulate rates, shown on the lower half of Figure 39, were substantially lower with the APS system at the 50, 75 and 100 percent power points. The difference is much smaller at the 25 percent power point and virtually the same at 2 percent power and at idle. Rather than the characteristic steep increase between 50 and 100 percent power, especially on approach to 100 percent load, the APS particulate rate was almost linear with power and relatively flat in comparison.

It may be argued that a 50 percent reduction in particulate is promising, but it falls short of that desired or possibly needed. This is the largest improvement yet found, however, with an engine change and is thought to be very encouraging. The accompanying increase in oxides of nitrogen may or may not be inherent in the system, but only additional parametric type experimentation will tell. The 50 percent reduction in gross particulate justifies substantial further study with injection systems since apparently this could offer reduced exhaust particulate.

Please refer to Tables D-88 and D-95 for the modal results in terms of concentration and various mass rates of both sulfate and particulate. Tables D-88 and D-91 are for the APS pump, and Tables D-92 to D-95 are for the new Robert Bosch standard system.

4. BaP and Organic Solubles

Table 52 is a summary listing of the mode-by-mode BaP and organic soluble percentages for both the standard and the APS pumps. Combining the modal data into cycle composites was done on Tables D-96 and D-97. The brake specific 13-mode rates are compared below.

	Cycle Composite	
Engine Configuration	BaP, μg/kw-hr	Org. Sol., %
Standard Pump	0.229	16.31
APS Pump	0.084	16.93

The above indicates a vast difference in BaP rate as a result of the pump. Referring to Table 52, it is evident that in only two of seven modes (APS pump) and three of seven modes (standard) was the BaP value reported above the minimum detectable. Thus, with only two data points of seven to even compare, the cycle composite can be easily overestimated by just the strength or inaccuracy of one point. Thus, the APS pump may indeed result in lower BaP, but this finding should be verified and confirmed through additional testing.

TABLE 52. SUMMARY OF PARTICULATE, BaP AND ORGANIC SOLUBLES FROM 8 x 10 SIZE GLASS FILTER SAMPLES MACK ETAY(B)673A ENGINE

Condition rpm/load %	Engine Configuration	Particulate Rate				BaP				Organic Solubles
		mg/m^3	g/hr	g/kg fuel	g/kw-hr	$\mu g/m^3$	µg/hr	µg/kg fuel	µg/kw-hr	
1450/2	Standard Pump	47.95	22.13	5.98	5.15	0.086	39.87	10.78	9.27	32.50
	APS Pump	61.87	27.65	6.01	3.84	BMD (1)	-----	-----	-----	36.19
1450/50	Standard Pump	119.78	80.26	3.50	0.74	BMD	-----	-----	-----	4.92
	APS Pump	53.64	35.48	1.43	0.30	BMD	-----	-----	-----	14.10
1450/100	Standard Pump	249.56	254.13	5.43	1.17	BMD	-----	-----	-----	7.38
	APS Pump	71.09	72.56	1.48	0.31	BMD	-----	-----	-----	12.57
Idle	Standard Pump	36.53	7.11	7.11	----	0.166	32.33	32.33	-----	21.30
	APS Pump	41.33	7.73	7.73	----	0.084	16.06	16.06	-----	23.69
1900/100	Standard Pump	132.46	180.88	3.26	0.75	BMD	-----	-----	-----	9.15
	APS Pump	56.50	75.64	1.37	0.31	BMD	-----	-----	-----	0
1900/50	Standard Pump	71.90	68.79	2.42	0.58	BMD	-----	-----	-----	4.54
	APS Pump	49.65	46.99	1.64	0.38	BMD	-----	-----	-----	9.72
1900/2	Standard Pump	45.63	27.84	4.16	6.47	0.135	82.88	12.28	19.13	38.65
	APS Pump	59.11	36.22	5.33	6.97	0.068	41.56	6.11	7.99	21.00

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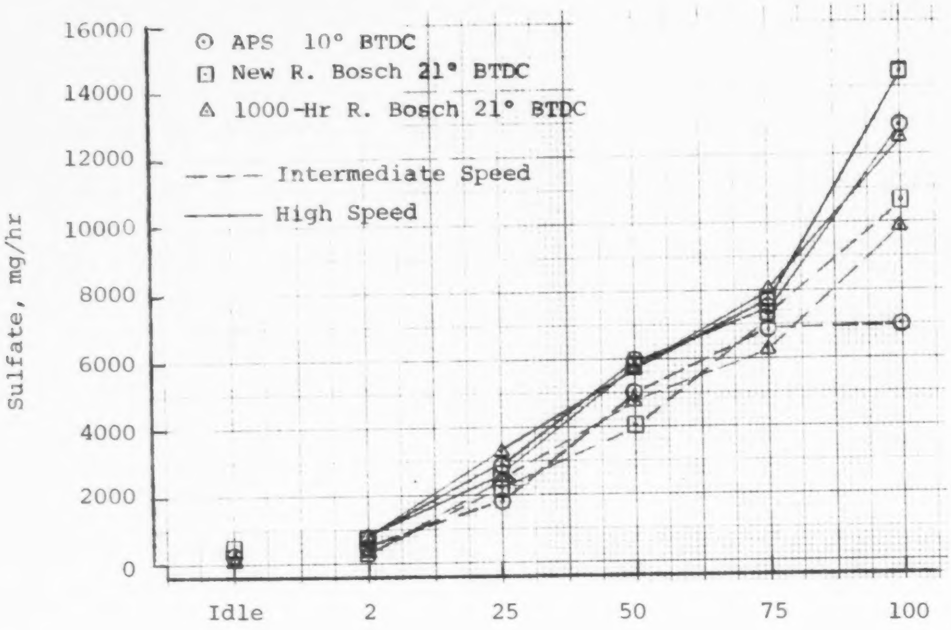
(1) Below Minimum Detectable



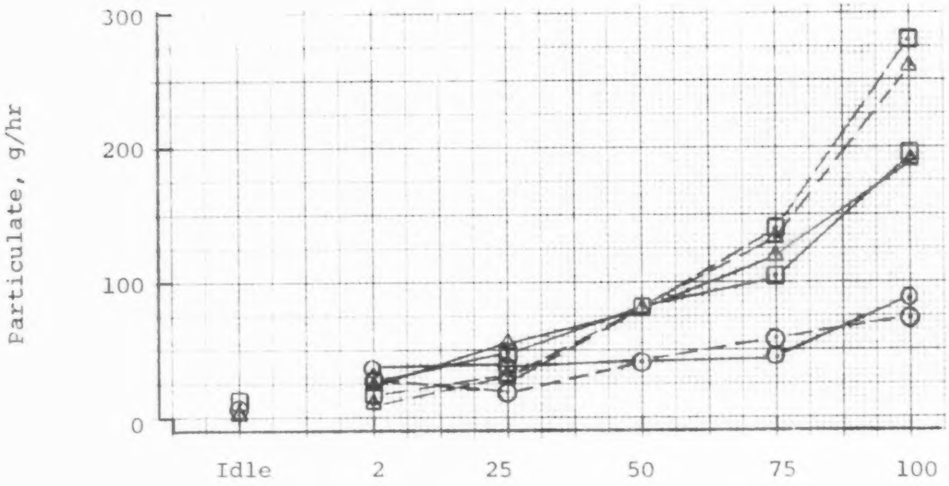


Figure 39. Particulate and Sulfate Modal Rates for Mack ETAY(B)673A with APS and Standard Pumps

5. Hydrogen, Carbon and Metal Content

The modal elemental analysis for H and C and the computed H/C mole ratio for the standard (new) pump and the American Bosch APS high-pressure system are listed below.

Comparison of Carbon and Hydrogen Content of Mack ETAY(B)673A with Standard and High-Pressure Fuel Injection

	Carbon		Hydrogen		H/C (1)	
Speed/Load	Std.	High Pres.	Std.	High Pres.	Std.	High Pres.
1450/2	46.40	43.45	6.35	6.19	1.63	1.70
1450/50	75.36	51.07	2.63	3.98	0.42	0.93
1450/100	77.52	47.34	1.87	0.54	0.29	0.14
Idle	38.87	24.12	5.21	2.00	1.60	0.99
1900/100	62.33	44.39	2.43	1.12	0.47	0.30
1900/50	68.34	50.87	3.75	4.22	0.65	0.99
1900/2	55.79	42.74	5.22	5.41	1.12	1.51

---

(1) Mole Ratio

The high-pressure injection system had no overall effect on changing the amount of carbonaceous, C, to the hydrocarbon, H, derived values. Some modes were lower and some higher, but the arithmetic average of the seven modes shows a H/C ratio of 0.88 for the standard pump versus 0.94 for the APS high-pressure system.

Table D-98 lists the metals and sulfur analyses performed by EPA-RTP. Sulfur and calcium values were reported for nearly every condition. Except for the two 2-percent power points, the APS pump produced particulate at least two and sometimes three times the standard pump. With the exception of the same 2-percent points, calcium was notably higher with the APS pump. No good reason for this behavior is apparent.

6. Particle Sizing

According to the plot of the "means" of the 7-mode particle size results on Figure 39a, the high-pressure injection system resulted in finer, lighter particulate than the standard engine. The new, standard Robert Bosch pump and injectors were used for particle size distribution experiments.

For modal size distributions for each configuration, please refer to Table D-99 and Figures D-8 and D-9. There appears to be a greater variation mode to mode with the APS pump than the standard pump. Both configurations appeared to have more modal effect than other engines similarly tested.

The following compares the two configurations.

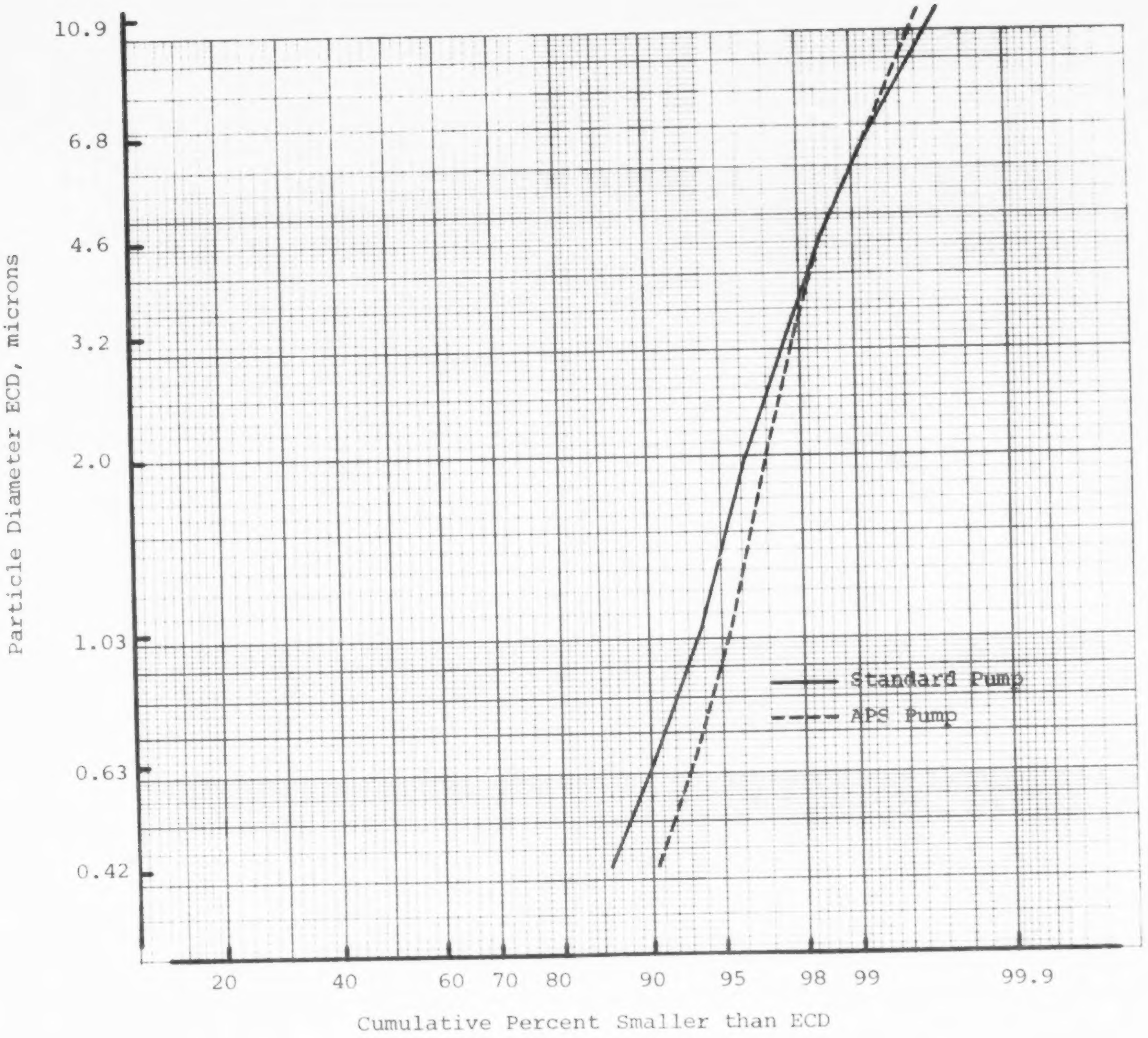


Figure 39a. Particle Size Distributions by "Means" for Mack ETAY(B)673A, via Impactor

Particle Diameter ECD, Microns	Cumulative Percent Smaller than ECD A. Bosch APS	 New R. Bosch
less than 10	99.6	99.7
5	98.6	98.6
2	97.0	96.2
1	95.3	93.6
0.5	91.9	88.0
0.42	86.0	90.5

The Anderson sampler only classified about 15 percent of the particulate from the standard engine and only about 10 percent of the particulate from the APS configuration.

7. DOAS

The DOAS results for the Mack ETAY(B)673A engine with standard and high-pressure pumps are given in Table 53. The average DOAS values listed below indicate little or no effect due to the pump configuration.

Configuration	DOAS Avg. LCA	 LCO	 TIA
A. Bosch APS Pump	18.1	6.6	1.7
Standard R. Bosch Pump, 1000-hr	11.8	5.8	1.8
New	13.6	6.3	1.7

There were some apparent differences between the LCA, i.e., lower LCA with standard pump than with the APS pump, but otherwise the LCO and TIA derived from the LCO were quite consistent.

TABLE 53. DOAS RESULTS FOR MACK ETAY(B)673A WITH VARIOUS INJECTION SYSTEMS

Configuration	DOAS[(a)]	1450 rpm 2	 50	 100	Idle	1900 rpm 100	 50	 2
APS High Press.	LCA	25.2	16.1	4.2	20.1	5.0	15.1	40.7
Inject. System	LCO	9.5	4.0	2.1	7.1	2.5	3.9	17.1
10° BTC	TIA	2.0	1.6	1.3	1.9	1.4	1.6	2.2
1000-hr Std.	LCA	14.5	10.8	6.8	11.5	5.8	15.6	17.4
Inject. System	LCO	7.0	5.1	5.0	5.9	4.3	6.8	6.5
21° BTC	TIA	1.9	1.7	1.7	1.8	1.7	1.9	1.8
New Std.	LCA	20.7	19.7	2.6	14.2	4.6	11.4	21.7
Inject. System	LCO	7.4	8.4	1.4	6.7	3.4	6.3	10.8
21° BTC	TIA	1.9	1.9	1.1	1.8	1.5	1.8	2.0

(a) Diesel Odor Analytical System

8. Aldehydes

The cycle composite aldehyde rates in mg/kw-hr and mg/kg fuel are summarized on Table 54. In some cases, there is good agreement between new and old standard pumps such as formaldehyde, hexanaldehyde and crotonaldehyde. In other cases, the data does not agree at all nor is there a consistent trend noticeable. The different pumps, run about one year apart, may have had some effect on aldehydes. The procedure and analysis was the same, but its variability could have contributed.

TABLE 54. CYCLE COMPOSITE ALDEHYDE RATES
MACK ETAY(B)673A

Aldehyde	Rate	A. Bosch APS High Pressure	R. Bosch 1000-hr Pump	R. Bosch New Pump
Formaldehyde	mg/kw-hr	27.44	16.59	17.05
	mg/kg fuel	117.25	66.84	72.85
Acetaldehyde	mg/kw-hr	15.92	0.94	8.17
	mg/kg fuel	68.03	3.78	34.90
Acetone	mg/kw-hr	14.89	------	12.13
	mg/kg fuel	63.60	------	51.82
Isobutyraldehyde	mg/kw-hr	3.15	31.79	6.77
	mg/kg fuel	13.47	128.12	28.93
Crotonaldehyde	mg/kw-hr	9.60	16.68	23.84
	mg/kg fuel	41.04	67.22	101.88
Hexanaldehyde	mg/kw-hr	33.99	20.18	20.59
	mg/kg fuel	145.22	83.87	87.97
Benzaldehyde	mg/kw-hr	74.67	-----	134.92
	mg/kg fuel	319.03	-----	576.46

Against this variable baseline data, comparison of the APS pump is made difficult. Formaldehyde and hexanaldehyde were higher while crotonaldehyde was lower. If one were to merely add the individual aldehyde rates together, an overall comparison could be made as follows.

Configuration		Aldehydes mg/kw-hr	LCA µg/litre
A. Bosch APS System		180	18.1
Standard R. Bosch System,	1000-hr	87	11.8
	New	223	13.6

When compared to the new pump, the APS was about the same. The 1000-hour standard pump was lower than either, just as the LCA from the DOAS data indicated. Recall that 13 FTP hydrocarbons were slightly higher with the APS pump. The major reason for the large difference in new versus 1000-hour pump results was the absence of benzaldehyde in the original experiments with the 1000-hour engine. Benzaldehyde accounted for over half of the "total aldehydes".

Please refer to Tables D-100 and D-101 that list the modal results for the APS and new Robert Bosch standard systems. These data, taken for seven operating modes, were used in calculating the cycle composites using weighting factors derived from the 13-mode test.

9. Specific Hydrocarbons

The various individual hydrocarbons listed on Table 55 show less difference between Robert Bosch pumps (old and new) than the aldehyde values previously discussed. The APS pump, in most cases, agreed best with the back-to-back test with the new Robert Bosch standard pump. The APS pump values were, except for toluene, always higher than the new pump, and the new pump values were, except for the negligible ethane rates, higher than the old 1000-hour pump.

The following lists the "total" of the eight hydrocarbons measured by adding together the values on Table 55.

Configuration	Hydrocarbons avg/kw-hr
A. Bosch APS System	127
Standard R. Bosch System, 1000-hr	79
New	102

As with aldehydes, the back-to-back (in time) American Bosch APS and Robert Bosch (new) are high and the 1000-hour engine is low. For modal values, please refer to Tables D-102 and D-103.

10. Summary

A 50-percent reduction in particulate was found with the Robert Bosch APS high-pressure injection system as compared to the standard Robert Bosch system used on the Mack ETAY(B)673A engine tested. Major reductions in visible smoke and particulate were found at 50, 75 and 100 percent power, giving essentially "flat" response versus power level. Although HC and CO seemed little affected, the APS system resulted in a 45-percent increase in NO emissions. A 4-percent improvement in fuel efficiency was noted. Particle size distribution was shifted toward finer particles by the high-pressure system. Aldehydes were fairly equivalent overall when compared to the new Robert Bosch standard pump. The same was found for the specific hydrocarbons in total. The major effect of the high-pressure APS system on reducing Diesel exhaust particulate justifies substantial additional research in the general area of fuel injection system characteristics as they may influence Diesel particulate production.

TABLE 55. CYCLE COMPOSITE SPECIFIC HYDROCARBON RATES
MACK ETAY(B)673A

Hydrocarbon	Rate	A.Bosch APS High Pressure	R. Bosch 1000-hr Pump	R. Bosch New Pump
Methane	mg/kW-hr	11.57	6.90	10.20
CH_4	mg/kg fuel	49.45	27.77	43.56
Ethylene	mg/kW-hr	69.16	45.03	52.76
C_2H_4	mg/kg fuel	295.52	181.18	225.42
Ethane	mg/kW-hr	0.48	0.68	0.38
C_2H_6	mg/kg fuel	2.05	2.74	1.61
Acetylene	mg/kW-hr	6.77	2.79	4.79
C_2H_2	mg/kg fuel	28.94	11.24	20.46
Propane	mg/kW-hr	0.62	---	0.43
C_3H_8	mg/kg fuel	2.64	---	1.83
Propylene	mg/kW-hr	25.08	17.96	21.50
C_3H_6	mg/kg fuel	107.18	72.26	91.86
Benzene	mg/kW-hr	7.41	4.48	5.24
C_6H_6	mg/kg fuel	31.66	18.01	22.38
Toluene	mg/kW-hr	5.68	0.78	6.46
C_7H_8	mg/kg fuel	24.27	3.15	27.61
TOTAL	mg/kW-hr	126.77	78.62	101.76
	mg/kg fuel	541.71	316.35	434.73

D. Effect of Fuel Residue

The effect of fuel composition on particulate has been investigated on both HDD engines(31,35) and LDD cars.(44) The method has been to simply measure particulate and other emissions while operating the engines/vehicles on different fuels that are either commonly available or could be representative of available fuels in the U.S. One such project included cetane and smoke suppressant additives.(31) Statistical analyses were then performed to see if particulate, sulfate and other fuel properties could be related to mass emission rates.

Fuel sulfur content is directly related to that measured as sulfate in the exhaust. No such single or even functional grouping of fuel parameters has been, so far, related to particulate such that its removal or modification would result in lower exhaust particulate. Thus, this project included, as one of the variables of interest, the evaluation of a "special" or modified fuel for reduced exhaust particulate. The study was hampered to a great extent since the fuel property to be modified was not identified.

It was speculated that part of the Diesel particulate might be a direct result of residual material in Diesel fuel which resembles microscopic-sized tarry substances in solution. These tiny particles resist combustion and could serve as nuclei for particle formation. Their boiling range is thought to be so high, relative to Diesel fuel itself, as to only partially burn to form a carbonaceous residue which is emitted as particulate.

To investigate this theory, a brief study of fuel properties that might define this residual matter in the fuel was made. Steam jet gum (ASTM D-481) is a possible indicator of the type of residue or matter in a distillate fuel that could participate in the mechanism of particulate formation. Namely, the residue or unaccounted-for matter in an ASTM D-86 thermal distillation may be an indicator of very heavy ends that really never completely burn or some of which never burn during the combustion event and thereby exit the engine as particulate. To try and describe the type of residue in terms of the "unaccounted-for" part of the ASTM D-86 thermal distillation may be incorrect, however.

Under Contract No. 68-02-1777 for EPA (Dr. Ron Bradow, Project Officer), five different Diesel fuels were used to characterize a variety of emissions from two HDD engines. Table 56 is a listing of fuel properties of the five fuels to which has been added the steam jet gum determination. Note the wide variation in this value, from 0.2 to 11.8 mg/100 mℓ. EM-293-F is the "National Average" fuel used in this project, and it has 8.6 mg/100 mℓ of gum.

Thinking that distillation and steam jet gum are interrelated somehow, it was decided to laboratory distill EM-239-F so as to eliminate the last 2 and 5 percent of the boiling range, determine the distillations for each 98 and 95 percent remainder fuels, and perform steam jet gum determinations on each.

Table 57 is a comparison of these findings, all with the same EM-239-F base material. For ease of comparison, the distillation data from Table 56 for EM-239-F is retabulated on Table 57. Note the drastic reduction in steam

TABLE 56. PROPERTIES OF THE FIVE TEST FUELS, CONTRACT 68-02-1777

Fuel code Fuel type	EM-238-F 2D emissions	EM-239-F "Nat'l. avg." No. 2	EM-240-F "Jet A"	EM-241-F "min. qual." No. 2	EM-242-F "premium" No. 2
Gum (D-481)					
mg/100 ml	9.9	8.6	0.2	11.8	2.2
Properties					
Gravity, g/ml	0.845	0.844	0.806	0.861	0.831
Gravity, °API	36.0	36.1	44.1	32.8	38.7
Cetane (D976)	48.6	48.7	47.4	41.8	53.0
Viscosity, cs (D445)	2.65	2.66	1.41	2.44	2.53
Flash point, °C (°F)	94 (202)	87 (189)	48 (118)	68 (155)	66 (150)
Sulfur, wt.% (D1266)	0.35	0.23	0.04	0.26	0.26
FIA: aromatics, %	29.8	21.6	13.0	34.6	12.4
olefins, %	1.6	0.8	3.4	1.0	0.8
saturates, %	68.6	77.6	83.6	64.4	86.8
Distillation (D86)					
IBP, °C (°F)	192 (378)	186 (366)	162 (324)	182 (360)	183 (362)
10%	213 (415)	216 (421)	181 (358)	216 (420)	213 (416)
20%	223 (434)	229 (444)	186 (366)	227 (440)	223 (434)
30%	233 (451)	239 (462)	190 (374)	240 (464)	231 (448)
40%	245 (473)	248 (479)	196 (384)	250 (482)	244 (472)
50%	257 (495)	257 (494)	201 (394)	258 (496)	254 (490)
60%	269 (517)	266 (511)	207 (405)	266 (510)	262 (504)
70%	281 (538)	275 (527)	214 (418)	277 (530)	271 (520)
80%	293 (560)	286 (547)	224 (436)	292 (558)	287 (548)
90%	312 (593)	303 (578)	238 (460)	301 (574)	301 (574)
95%	331 (628)	320 (608)	249 (481)	311 (592)	310 (590)
EP	349 (660)	337 (640)	268 (515)	327 (620)	327 (620)
recovery, %	99	99	99	99.5	99.0
residue, %	1	1	1	0.5	1.0
loss, %	0	0	0	0.0	0.0
Carbon, wt. %	86.8	86.8	86.2	87.5	86.3
Hydrogen, wt. %	12.9	13.0	13.7	12.3	13.5
Nitrogen, wt. %	0.005	0.005	0.006	0.024	0.008

jet gum afforded by separating off the 2 percent of the material with the highest distillation temperature. Additional removal, as shown by the last column for 95 percent (5 percent separated), had essentially no effect on the steam jet gum. Thus, it may be concluded that, if the highest boiling range materials, say 2 percent of fuel with highest boiling temperature, were removed, then a substantial reduction of steam jet gum could be expected, on the order of 8.6 to 1.8 mg/100 mℓ, or approximately 80 percent reduction.

TABLE 57. COMPARISON OF GUM AND BOILING RANGE FOR EM-239-F AND SPECIAL DISTILLED CUTS OF EM-239-F DIESEL FUEL

	EM-239-F "Nat'l Avg." No. 2	Special Distillations 98%	95%
Gum (D481) mg/100 ml	8.6	1.8	1.6
Distillation (D86)			
IBP, °C (°F)	186(366)	189(372)	188(371)
10%	216(421)	218(424)	219(426)
20%	229(444)	231(447)	230(446)
30%	239(462)	239(463)	239(463)
40%	248(479)	248(479)	248(478)
50%	257(494)	257(495)	256(493)
60%	266(511)	266(510)	264(507)
70%	275(527)	271(520)	273(523)
80%	286(547)	287(549)	284(543)
90%	303(578)	302(576)	299(571)
95%	320(608)	317(603)	314(598)
EP	337(640)	332(630)	329(625)
Recovery, %	99	98.8	98
Residue, %	1	1.2	2
Loss, %	0	0	0

The key question is: "Would such a change in fuel properties result in lower particulate?" Another question is: "Is there some other property that might influence exhaust particulate?" The answer to both questions is unknown at this time. There are laboratory tests that evaluate residue type properties of lubricating oils such as carbon residue by ASTM D-189 (Conradson) or by ASTM D-524 (Ramsbottom). How well these tests might relate to the exhaust particulate rate of a given engine is unknown but worthy of mention in passing.

During a meeting with the Project Officer on November 10, 1976, it was mentioned that a special fuel for laboratory testing might be the EM-239-F distilled to remove the 2 percent fraction of highest boiling range. An estimate of the cost to perform such a distillation on sufficient fuel for full-size engine evaluation was obtained from a specialty refiner located near

Houston, Texas. It was found that the fuel cost was beyond the scope of the project, and further efforts were abandoned in favor of more complete evaluation of other effects already discussed.

The area of fuel and lubricant effects, and especially fuel/lubricant modification to achieve lower particulate, demands much more work. Clearly, this area of study justifies a project or program of its own as was indicated by the preliminary study made under this project. It is a difficult area of study, yet the potential benefits may be much greater in reducing particulate and organic matter than mechanical methods such as combustion system improvement or exhaust after-treatment.

VI. RESULTS OF LIGHT-DUTY VEHICLE EVALUATION

The results of the four light-duty vehicles are described by emission category. For description of test methods, procedures and equipment, please refer to Section III.

A. Regulated Emissions and Fuel Economy

The transient test procedures known as the FTP, SET and FET were the basis for measurement of gaseous emissions of HC, CO and NO_x as well as fuel economy.

1. Emission Standards

The contractural requirement to report all data and results in modernized metric units (SI) requires a statement of equivalent emission standards for 1973 and later model year light-duty cars in grams per kilometer (g/km) for understanding. Table 58 lists the HC, CO and NO_x limits in g/km with those published in appropriate Federal Registers in g/mile in parentheses. The conversion was based on 1.609 km equal to 1 mile and were rounded to the same number of decimals as the published limit. The metric equivalent levels are approximately 62 percent of the mixed metric-English units.

TABLE 58. FEDERAL LIGHT-DUTY EMISSION STANDARDS

Year	Units	HC	CO	NO_x
1973-1974	g/km (g/mile)	2.1 (3.4)	24 (39)	1.9 (3.0)
1975-1976	g/km (g/mile)	0.9 (1.5)	9.3 (15)	1.9 (3.1)
1977-1979	g/km (g/mile)	0.9 (1.5)	9.3 (15)	1.3 (2.0)
1980	g/km (g/mile)	0.25 (0.41)	4.35 (7.0)	1.3 (2.0)
1981-1983	g/km (g/mile)	0.25 (0.41)	2.1(a) (3.4)	0.62(b) (1.0)

(a) CO standard can be waived to 4.35 g/km (7.0 g/mile) for 1981-1982 by Administrator after Public Hearing.

(b) NO_x standard can be waived to 0.93 g/km (1.5 g/mile) by Administrator for innovative technology.

2. Emissions and Fuel Economy Results

Tables 59 and 60 are summaries of the gaseous emissions of HC, CO and NO_x (in g/km), fuel consumption (in l/100 km) and the reciprocal of fuel consumption, fuel economy in mpg. Table 59 lists the results for the gasoline and Diesel powered Oldsmobile Cutlass cars. Table 60 lists the results for the gasoline and Diesel powered Volkswagen Rabbit cars. Each SwRI value is the average of at least three replicates. In the case of the FTP results, two complete 23-minute urban driving cycles were run producing four bag samples. The first three bags were used to compute the 1975 FTP results; the first two bags, taken during the first cold-start, 23-minute cycle, were used to compute an FTP cold; and the last two bags, taken during the hot-start, second 23-minute cycle, were used to compute an FTP hot.

A total of 11 replicate FTP hot runs were made over a three-day period with the Oldsmobile Diesel car with excellent repeatability both run-to-run and day-to-day. The standard deviation and coefficient of variation statistics are also shown on Table 59. Prior to the Volkswagen Rabbit gasoline car being shipped to SwRI, a test was made by the EPA Research Triangle Park (RTP) Laboratories in North Carolina. These results are listed on Table 60 for comparison.

The four car results may be compared to Federal standards, listed in Table 58. The 0.25 g/km (0.41 g/mile) 1980-1983 limit for HC was met by the Rabbit Diesel but exceeded by the experimental Oldsmobile 350 Diesel tested. The 1981-1983 CO limit of 2.1 g/km (3.4 g/mile) was met by both Diesel cars, while the 1981-1983 limit of 0.62 g/km (1.0 g/mile) NO_x was not met by the Oldsmobile 350 Diesel car. The 1980 limit of 1.3 g/km (2.0 g/mile) NO_x was achieved by both cars. Neither car achieved the 0.25 g/km (0.4 g/mile) NO_x research goal.

According to Table 59 1975 FTP results, it is evident that HC is higher, CO and NO_x about the same, and fuel consumption in ℓ/100 km lower (fuel economy in mpg higher) for the Diesel as compared to the gasoline-powered Oldsmobile Cutlass. During the cold portion of the test, the CO from the Diesel was half that of the gasoline engine, while during the hot part of the run the CO from the gasoline was about half that of the Diesel. This is an apparent indication of the effects of the oxidation catalyst equipped gasoline Cutlass.

HC was consistently lower from the gasoline engine, and, as the vehicle and engine continued to run, the difference became greater. The 0.06 g/km HC during the FET was about 30 percent of the 0.21 g/km from the experimental Diesel Cutlass. NO_x from the Diesel decreased to 0.59 g/km during the SET and FET, while NO_x from the gasoline car stayed at or near the 0.85 g/km of the 1975 FTP.

Fuel consumption of the Diesel Cutlass was consistently 26 to 29 percent less than the gasoline car regardless of the driving cycle. In terms of fuel economy, the percent increase in miles per gallon, based on the gasoline car, was from 35 to 40 percent. In summary of the fuel economy results of Table 59, the specific experimental Diesel Cutlass tested gave a 21.7 mpg city and 31.3 mpg highway estimates for a combined 25.2 mpg. The gasoline Cutlass tested gave estimates of 15.6 mpg city and 23 mpg highway for a combined 18.2

TABLE 59. AVERAGE HC, CO, NO_x AND FUEL RESULTS FOR DIESEL- AND GASOLINE-POWERED OLDSMOBILE CUTLASS CARS

Cycle	Vehicle	By	Emission Rate, g/km HC	CO	NO_x	Fuel Cons. ℓ/100 km	Fuel Econ. mpg
1975 FTP	350 Diesel	SwRI	0.47	1.24	0.70	10.84	21.7
			(0.76)	(2.00)	(1.13)		
	260 Gasoline	SwRI	0.24	1.34	0.85	15.11	15.6
			(0.39)	(2.16)	(1.37)		
		EPA[a]	0.59	6.6	2.0		15.5
FTP Cold	350 Diesel		0.59	1.37	0.70	11.46	20.5
			(0.95)	(2.20)	(1.13)		
	260 Gasoline	SwRI	0.39	2.35	1.02	15.92	14.8
			(0.63)	(3.78)	(1.64)		
FTP Hot	350 Diesel	SwRI	0.36	1.12	0.69	10.13	23.3
			(0.58)	(1.80)	(1.11)		
	Std. Dev.		0.02	0.05	0.04	0.33	0.78
	Coef. of Var., %		4.9	4.6	5.1	3.3	3.3
	260 Gasoline	SwRI	0.14	0.55	0.68	14.27	16.5
			(0.22)	(0.88)	(1.09)		
SET	350 Diesel	SwRI	0.27	0.79	0.59	8.74	26.9
			(0.43)	(1.27)	(0.95)		
	260 Gasoline	SwRI	0.08	0.53	0.86	11.83	19.9
			(0.13)	(0.85)	(1.38)		
FET	350 Diesel	SwRI	0.21	0.63	0.59	7.51	31.3
			(0.34)	(1.01)	(0.95)		
	260 Gasoline		0.06	0.12	0.88	10.24	23.0
			(0.10)	(0.19)	(1.42)		
		EPA[a]					20.2

( ) values in parentheses are in grams/mile

(a) EPA 1977 Certification values for Family 730 H2O

TABLE 60. AVERAGE HC, CO, NO_x, AND FUEL RESULTS FOR DIESEL- AND GASOLINE-POWERED VOLKSWAGEN RABBIT CARS

			Emission Rate, g/km			Fuel Cons.	Fuel Econ.
Cycle	Fuel	By	HC	CO	NO_x	ℓ/100 km	mpg
1975 FTP	Diesel	SwRI	0.23 (0.37)	0.49 (0.79)	0.54 (0.87)	5.51	42.7
		EPA (a)	(0.20)	(1.0)	(1.2)		39
	Gasoline	SwRI	0.14 (0.23)	2.30 (3.70)	0.63 (1.01)	9.56	24.6
	Gasoline	EPA (b)	(0.17)	(2.00)	(0.84)		21.3
		EPA (c)	(0.20)	(1.00)	(0.90)		24
FTP Cold	Diesel	SwRI	0.38 (0.61)	0.57 (0.92)	0.54 (0.87)	5.63	41.9
	Gasoline	SwRI	0.18 (0.30)	2.87 (4.62)	0.67 (1.08)	9.91	23.8
FTP Hot	Diesel	SwRI	0.13 (0.21)	0.44 (0.71)	0.55 (0.89)	5.25	44.8
	Gasoline	SwRI	0.12 (0.19)	1.94 (3.12)	0.60 (0.96)	9.60	25.4
SET	Diesel	SwRI	0.09 (0.15)	0.34 (0.55)	0.50 (0.81)	4.51	52.2
	Gasoline	SwRI	0.03 (0.05)	0.19 (0.30)	1.01 (1.62)	7.43	31.7
FET	Diesel	SwRI	0.08 (0.13)	0.31 (0.50)	0.52 (0.84)	4.39	53.7
		EPA (a)					52
	Gasoline	SwRI	0.03 (0.05)	0.03 (0.05)	1.22 (1.96)	6.53	36.1
	Gasoline	EPA (b)					34.5
		EPA (c)					37.0

( ) values in parentheses are in grams/mile

(a) EPA 1977 certification value for Family D

(b) single run performed by EPA RTP

(c) EPA 1977 certification values for Family 38 mpg. The combined values are based on 55 and 45 percent time weighting to the city and highway estimates.

Except for the FTP hot test on Table 60, the Volkswagen Rabbit Diesel HC were always measurably higher than that from the gasoline-powered Rabbit. The CO, although much less from the Diesel during the FTP, was higher than the gasoline engine during the SET and FET. Apparently, the oxidation catalyst-equipped gasoline Rabbit resulted in very low CO levels during the higher average speed driving cycles. NO_x was slightly less from the Diesel during the FTP while NO_x was lower, about half that of the gasoline Rabbit during the FET and SET.

Thus the comparison of emissions from the Diesel- and gasoline-powered pair of Rabbits depends on driving cycle as it did for the pair of Cutlass cars. The oxidation catalyst apparently is very effective in reducing CO and HC to very low levels, lower than the Diesel during the higher average speed and road load driving typified by the SET and FET. However, NO_x is higher from the gasoline cars during the FET and SET. The Diesel car emissions may be considered to be somewhat stable for all three types of transient cycles, while the gasoline-powered car emissions seem to be dependent on driving cycle in their behavior.

The fuel consumption rates for the Diesel Rabbit were 42 percent lower by the 1975 FTP, 39 percent lower by the SET, and 33 percent lower by the FET relative to and based on the gasoline car fuel consumption in ℓ/100 km. In terms of fuel economy, the percent increase in miles per gallon for the Diesel relative to and based on the gasoline data of Table 60 was 74 percent by the 1975 FTP, 65 percent by the SET, and 49 percent by the FET.

In summary of the fuel economy results of Table 60, the Diesel-powered Rabbit tested gave estimates of 42.7 mpg city and 53.7 mpg highway, for a combined rating of 47.0 mpg. The gasoline-powered Rabbit gave estimates of 24.6 mpg city and 36.1 mpg highway, for a combined rating of 28.7 mpg. It is interesting to compare these values with those given for the Diesel Rabbit in Reference 65 of 39 mpg city, 52 mpg highway, and 44 mpg combined. The gasoline estimates also compare well with those given in Reference 65 of 24 mpg city, 37 mpg highway, and 28 mpg combined.

For additional detail please refer to Appendix E, tabulations for each car and the computer printout results for each type of test. They are grouped by car. Tables E-1 through E-24 are for the Oldsmobile Diesel while Tables E-25 through E-40 are for the Oldsmobile gasoline-fueled car. Tables E-41 through E-56 are for the VW Rabbit Diesel. Tables E-57 through E-72 contain the detailed results for the gasoline-powered Rabbit.

B. Smoke Results

Visible smoke from Diesels used in heavy-duty vehicles has been regulated since 1970 by the EPA. No Federal regulations or test for smoke applies to Diesel cars. For purposes of this research, smoke was measured during replicate cold start 1975 FTP, CFDS (SET), and FET cycles.

1. 1975 FTP Smoke

Of the three transient cycles, operation over the urban driving schedule, especially the first 505 seconds of the test, produces the most noticeable smoke discharges.

Of importance are those types of operation that might produce the maximum visible smoke during both cold and hot portions of the test. Table 61 lists the most important results of a visual analysis of the continuous smoke traces obtained from both Diesel-powered cars. The initial cold start resulted in a momentary peak value of 16 and 73 percent opacity for the Cutlass and Rabbit Diesels, respectively. The cold idle, which occurs immediately after engine start, produced a relatively low 4 to 5 percent opacity for the Cutlass and Rabbit Diesels.

Next, the peak opacity during the first acceleration, to 90.1 km/hr (56 mph), resulted in a noticeable peak of 21 percent for the Cutlass. The second idle, at 125 seconds into the test, gave an average of 5 percent opacity from the Cutlass and 0.5 percent opacity from the Rabbit.

TABLE 61. AVERAGE EXHAUST SMOKE OPACITY RECORDED DURING REPLICATE 1975 FTP CYCLES

Smoke Condition	Cutlass Diesel	Rabbit Diesel
Cold Start Portion of Cycle		
Cold Start, Peak %	16.3	72.9
Cold Idle, Average % (after start)	4.4	4.5
First Accel, Peak % (after cold idle)	21.4	7.4
Idle at 125 sec, Average %	5.2	0.5
Accel at 164 sec, Peak % (to 90.1 km/hr)	19.4	39.4
Hot Start Portion of Cycle		
Hot Start, Peak %	7.8	27.4
Hot Idle, Average % (after start)	4.1	0.4
First Accel, Peak % (after hot idle)	7.5	3.0
Idle at 125 sec, Average % (during final 505 sec)	4.3	0.3
Accel at 164 sec, Peak % (to 90.1 km/hr, during final 505 sec)	16.6	37.7

Starting at 164 seconds of the urban cycle, the vehicle was accelerated from rest to 90.1 km/hr (56 mph). This acceleration generally requires maximum power or close to maximum power from most Diesel-powered cars. The acceleration peak opacity was 19 percent for the Cutlass and 39 percent for the Rabbit.

The results for the same part of the driving schedule but from a hot start are listed on the lower half of Table 61. These may be directly compared to the cold engine behavior. The Cutlass hot start and first acceleration values were less than the cold start, while both idles, of 4 percent opacity, were about the same as the cold portion of the test. The acceleration to 90.1 km/hr was slightly lower.

The Rabbit Diesel exhibited a trend of substantially lower idle smoke when the engine was warmed up with a negligible opacity measured. The acceleration to 90.1 km/hr produced about the same opacity as measured during the cold portion of the test. To place this discussion of visible exhaust smoke into perspective, it should be noted that 3 to 5 percent opacity by the EPA smokemeter is at the limit of smoke visibility. Most of the time, both cars operated in this area with brief, but noticeable, excursions during rapid throttle movement and when accelerating at maximum or near maximum power.

Figures 40 and 41 are typical cold start idle-accel to 90.1 km/hr (56 mph) for both Diesel cars. The trace represents the first 300 seconds of cold start and was considered typical. All traces were based on a chart speed of 76.2 mm/min (3 inches/min) with zero opacity equal to 100 percent of chart. The speed trace was calibrated at 96.5 km/hr (60 mph) equal to 100 percent of chart and zero speed equal to zero on the chart. In the case of the Oldsmobile Diesel, the trace is of the third test. The Rabbit Diesel chart, Figure 41, was for the second test.

In analyzing the smoke traces on Figures 40 and 41, careful attention must be paid the physical distance between recorder pens (offset) since a two-pen overlapping recorder was used. Contrary to what some charts show, acceleration of the engine, vehicle, and smoke output occurred essentially at the same time. Each major chart division from right (engine start) to left is 24.5 mm and is equal to 20 seconds.

Table F-1 is a complete set of readings for the three runs for the Cutlass Diesel and the two replicates for the Rabbit Diesel. These data are provided for additional run-to-run analysis of the highlights listed in Table 61.

2. SET and FET Smoke

Tables F-2 and F-3 list the visual evaluation made of the smoke measured during the sulfate (SET) and highway economy (FET) cycles. The SET and FET represent cycles of increasing average speed with fewer starts and stops relative to the FTP. These cycles progressively reduce the effect of vehicle inertia (weight) and increase the effect of road load. Thus, it would be expected that more importance be given to cruise than to the accelerations, as was the case with the FTP. The visual smoke readings listed in Table F-2 and F-3 are lower in level than that measured in Table 61 and are therefore of less concern.

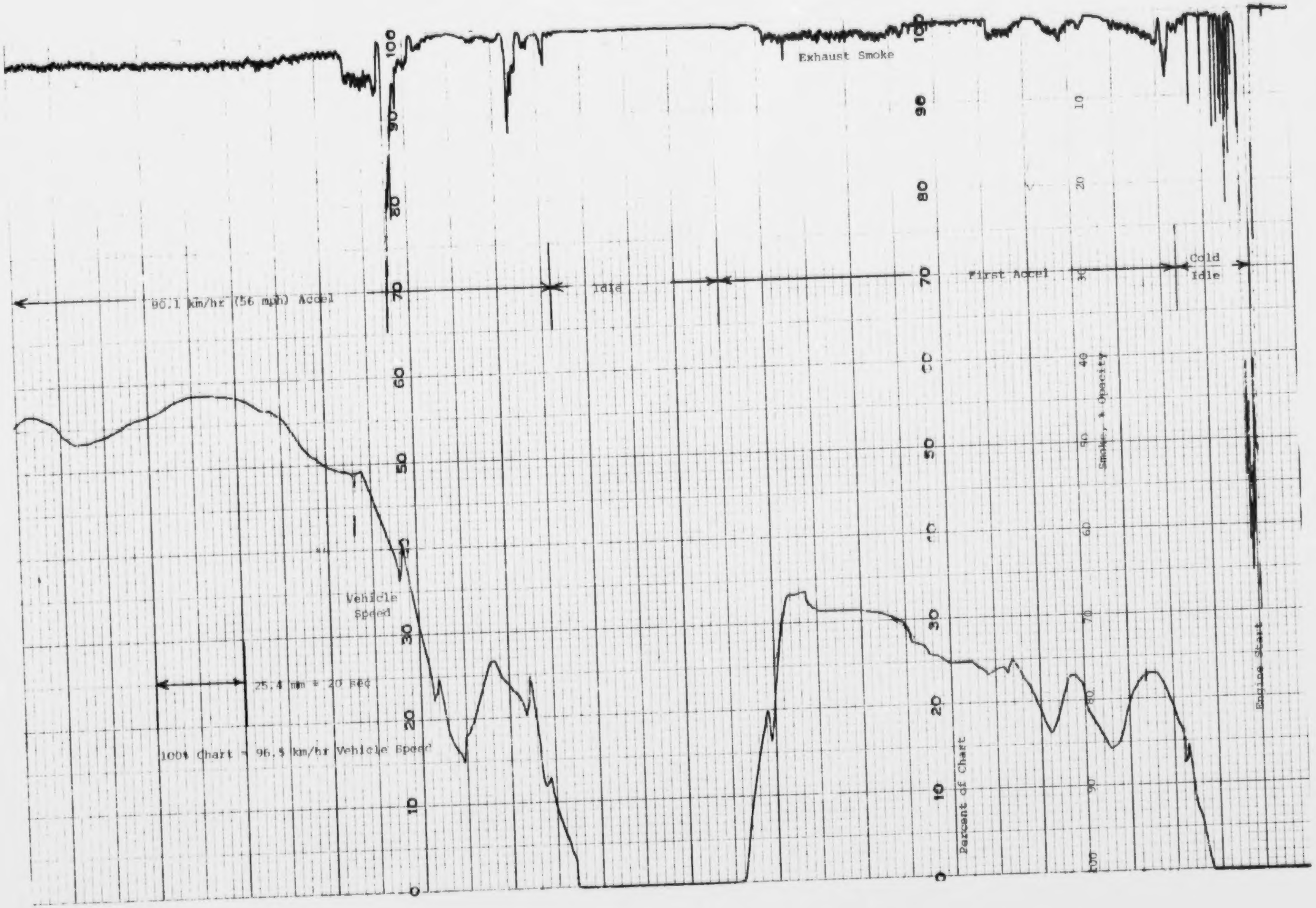


Figure 40. Typical Oldsmobile Cutlass Diesel "Cold Start" Smoke Trace

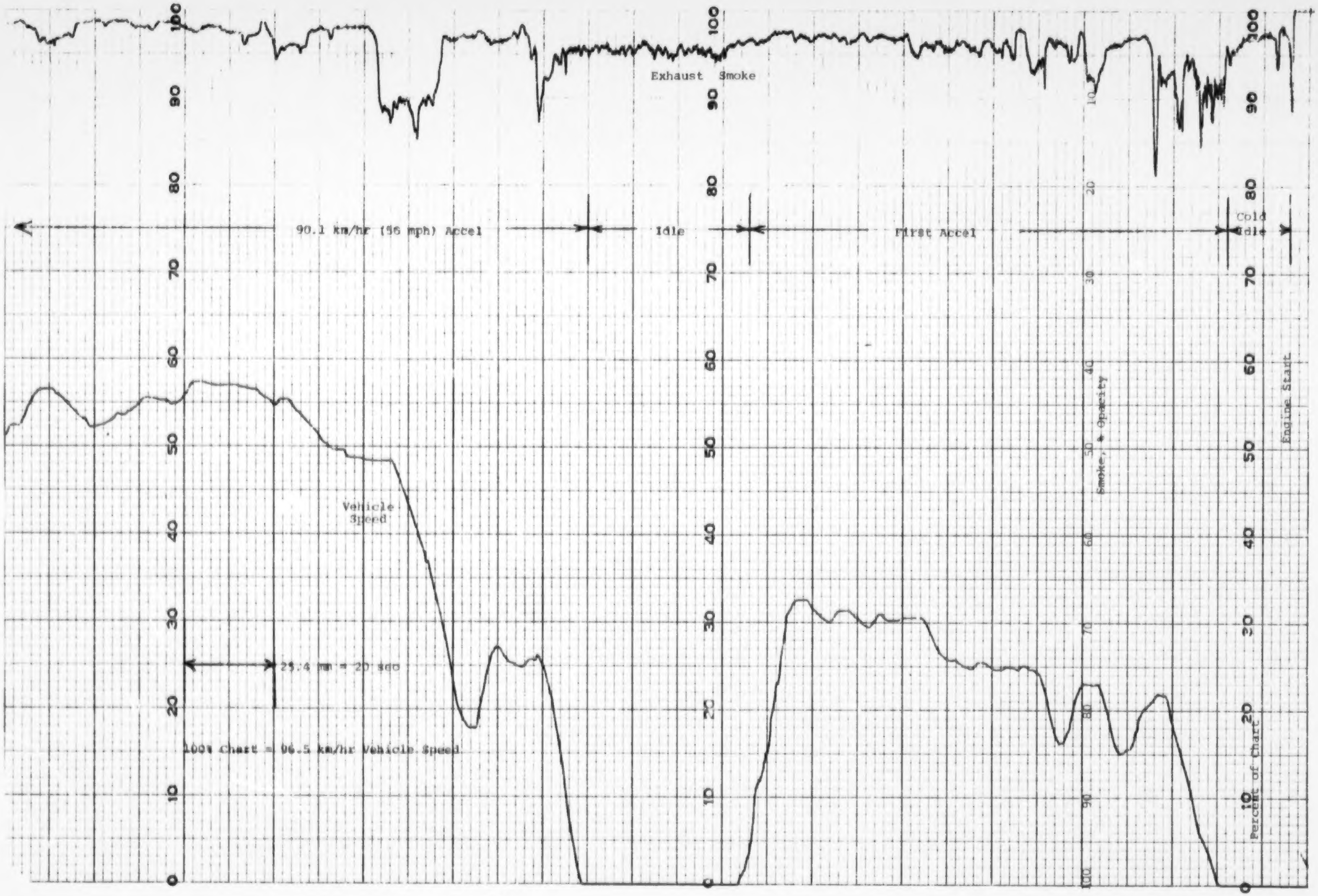


Figure 41. Typical Volkswagen Rabbit Diesel "Cold Start" Smoke Trace

Passenger cars equipped with Diesel engines should have an invisible exhaust if they are to be equal in terms of exhaust opacity to vehicles powered by gasoline-fueled engines. The data on Tables 61 and F-1 through F-3 illustrate the overall low smoke tendencies of both Diesel cars and also point up those areas or modes of operation in which the smoke is easily noticeable. Cold operation and acceleration are those types of running that will result in smoke discharges from these two cars that will be of concern.

As mentioned earlier, the limit of visibility by the EPA (PHS) smokemeter is taken at 3 to 4 percent opacity. Both vehicles produced average smoke outputs (by visual estimation of the continuous traces) at this level (in the case of the Oldsmobile) and slightly below this level (in the case of the VW) during the 1975 FTP. During the SET and FET, the overall estimates of the two cars were essentially the same and both quite low in smoke.

C. Particulate

In order to achieve a sufficient sample and because there is no convenient means to switch particulate samples at the 505-second point in the city driving schedule, all cold start FTP's were for the entire 23 minutes on a given filter. The 10-minute soak period was then observed and then an additional 23-minute city driving cycle repeated from a hot start. The 1975 FTP is a weighted combination of the cold and hot runs by the expression: 1975 FTP = 0.43 FTP cold + 0.57 FTP hot. The other two transient driving cycles were from a hot start with the sample for the SET and for the FET collected on separate filters.

Table 62 lists the particulate emission rates of the four LDV's. These rates are based on both duplicate fiberglass and duplicate Fluoropore filters taken at the same time during FTP cold, FTP hot, FET and SET experiments. The rates are in g/hr and g/kg fuel and g/km. The individual run results, on which the Table 62 averages are based, are listed on Tables F-4 through F-7 for the four cars.

Figure 42 depicts the emission rates for both Diesel and gasoline cars for each test procedure. The Diesel rates are reasonable and consistent with prior results and indicate the Cutlass powered by an experimental Diesel engine to have on the order of twice the particulate rate of the Rabbit.

The filters from the gasoline-powered Cutlass and Rabbit cars tested had a negligible amount of exhaust particulate in comparison to the Diesel cars. The appearance of the sample filters confirmed the absence of the black carbonaceous matter typical of Diesels and inferred that the particulate that was collected was to some extent sulfate. Thus, the bar chart representation of Figure 42 for the gasoline cars is very low relative to the Diesel.

To enable some general comparison, the ratio of Diesel to gasoline car particulate rate was computed from Table 63 data. The results are listed in Table 63 and indicate that the Cutlass experimental Diesel emits on the order of 22 to 147 times the gasoline engine particulate, while the ratio ranged from 41 to 101 times for the Diesel Rabbit compared to the gasoline Rabbit.

If the 1975 FTP, SET and FET ratios are simply averaged, an overall ratio of 54 times the gasoline Cutlass particulate and 82 times the gasoline Rabbit particulate was measured from their Diesel counterparts. These ratios indicate

TABLE 62. AVERAGE PARTICULATE EMISSION RATES FOR DIESEL AND GASOLINE PASSENGER CARS

Test	Vehicle	Diesel g/hr	Gasoline g/hr	Diesel g/kg fuel[a]	Gasoline g/kg fuel[a]	Diesel g/km	Gasoline g/km
1975 FTP	Cutlass	18.00	0.208	6.30	0.050	0.573	0.0056
	Rabbit	5.68	0.133	3.93	0.059	0.182	0.0042
FTP Cold	Cutlass	20.07	0.263	6.58	0.071	0.628	0.0084
	Rabbit	6.35	0.156	4.23	0.068	0.202	0.0050
FTP Hot	Cutlass	16.43	0.167	6.09	0.034	0.523	0.0036
	Rabbit	5.17	0.095	3.70	0.043	0.165	0.0030
SET	Cutlass	20.16	0.544	4.86	0.111	0.360	0.0097
	Rabbit	9.19	0.091	4.22	0.030	0.161	0.0017
FET	Cutlass	23.08	1.056	4.68	0.181	0.298	0.0136
	Rabbit	12.18	0.120	4.23	0.032	0.157	0.0016

(a) Mass per unit of fuel consumed based on average fuel consumption by carbon balance for respective test cycle.

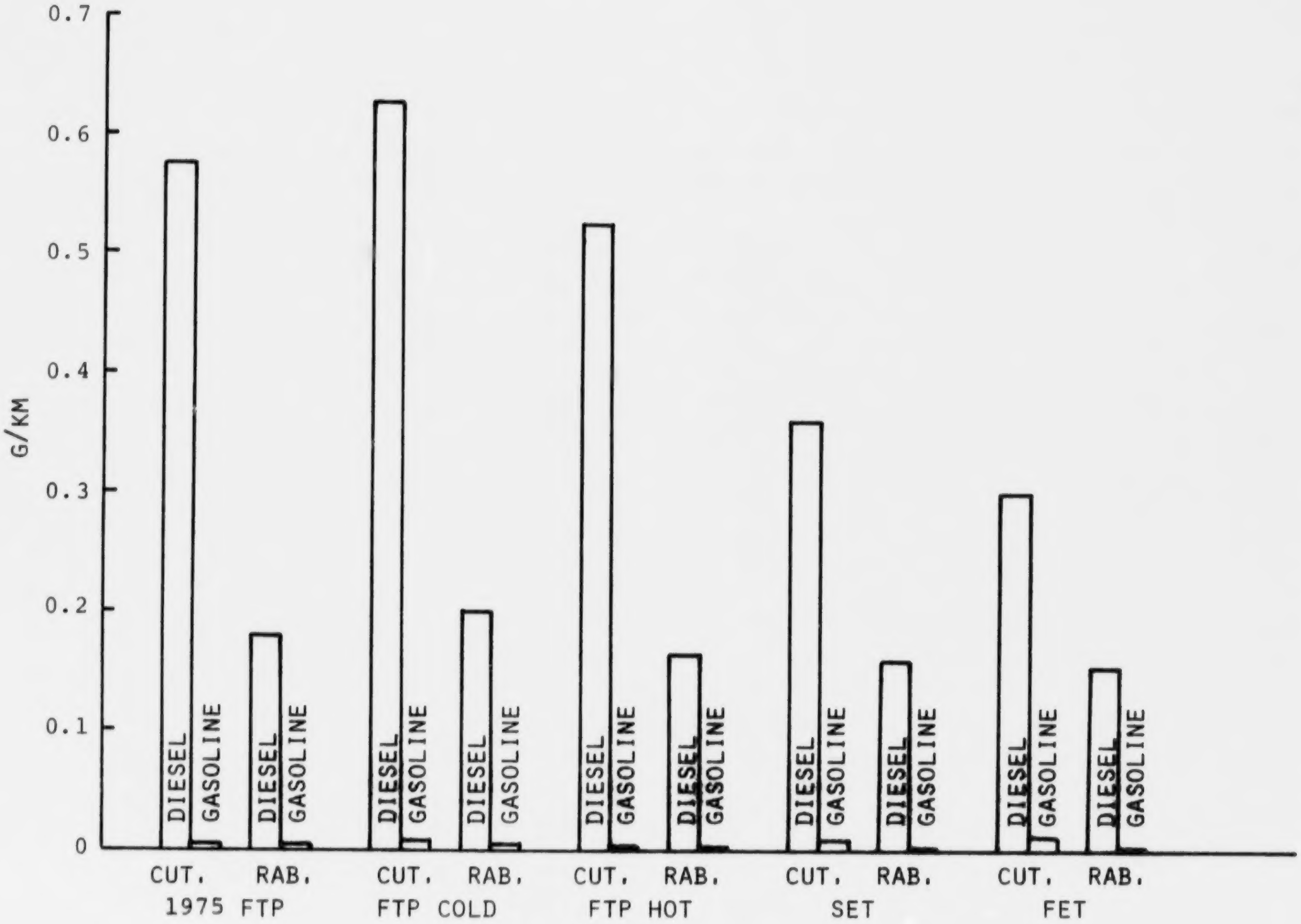


Figure 42. Particulate Emission Rates for Diesel- and Gasoline-Powered Passenger Cars

TABLE 63. DIESEL- AND GASOLINE-POWERED CAR PARTICULATE RATE COMPARISON

	Cutlass			Rabbit		
Test	Diesel g/km	Gasoline g/km	Ratio(a)	Diesel g/km	Gasoline g/km	Ratio(a)
1975 FTP	0.573	0.0056	102	0.182	0.0038	47
FTP Cold	0.628	0.0084	75	0.202	0.0050	41
FTP Hot	0.523	0.0036	147	0.165	0.0030	55
SET	0.360	0.0097	37	0.161	0.0016	99
FET	0.298	0.0136	22 54 (b)	0.157	0.0016	101 82 (b)

(a) $\frac{\text{Diesel}}{\text{gasoline}}$

(b) average of 1975 FTP + SET + FET

the Diesel-powered car may produce more particulate than expected relative to the oxidation-catalyst-equipped unleaded-gasoline-fueled car. This is the first such comparison of the specific car makes and models involved and was performed identically using the same procedures, number of replicates, and equipment. The dilution tunnel was cleaned and recalibrated between the Diesel and gasoline car testing.

Apparently, the unleaded clear fuel, oxidation catalyst, spark ignited, Otto cycle engine produces even less particulate than is commonly thought. The very low rates, on the order of 5 to 10 mg/km (0.005 to 0.01 g/km) may prove to be even more difficult for the Diesel car to approach. The appearance of the filters and the negligible to very low weight gain attest to the very low particulate rates relative to the Diesel. Earlier estimates placed the Diesel at, say, 10 to 20 times the clear (unleaded) gasoline engine. This was, however, the first opportunity for a direct comparison to be made by SwRI.

D. Sulfate

Table 64 is a compilation of the various sulfate rates for both types of cars. Recall that the Diesel cars were fueled with a "National Average" fuel sulfur content of 0.23 percent by weight, while the two gasoline cars were fueled with a "National Average" gasoline sulfur content of 0.03 percent by weight. All other factors being equal, the higher the fuel sulfur content, the higher the sulfate. The two gasoline cars were run for 805 km (500 miles) of modified MVMA durability with the 0.03 percent sulfur fuel as preconditioning prior to start of particulate-sulfate testing.

Figure 43 compares the sulfate mg/km rates of the Diesel to the gasoline and is based on data listed in Table 64. The cold and hot FTP results show

TABLE 64. AVERAGE SULFATE EMISSION RATES FOR DIESEL- AND GASOLINE-POWERED PASSENGER CARS

Test	Vehicle	Sulfate Emission Rate mg/hr	Sulfate Emission Rate mg/kg fuel	Sulfate Emission Rate mg/km	As % S in Fuel
1975 FTP	Cutlass Diesel	313.0	108.6	9.962	1.57
	Cutlass Gasoline	43.5	13.0	1.373	1.59
	Rabbit Diesel	115.2	79.5	3.662	1.24
	Rabbit Gasoline	1.3	0.6	0.041	0.06
FTP Cold	Cutlass Diesel	401.7	131.6	12.786	1.91
	Cutlass Gasoline	2.5	0.7	0.079	0.07
	Rabbit Diesel	138.5	92.2	4.395	1.34
	Rabbit Gasoline	0.9	0.4	0.029	0.04
FTP Hot	Cutlass Diesel	246.1	91.2	7.832	1.32
	Cutlass Gasoline	74.4	22.4	2.351	2.40
	Rabbit Diesel	97.7	69.9	3.110	1.02
	Rabbit Gasoline	1.6	0.7	0.051	0.08
SET	Cutlass Diesel	578.0	90.2	10.326	1.30
	Cutlass Gasoline	728.0	148.8	12.994	16.00
	Rabbit Diesel	244.2	114.2	4.362	1.66
	Rabbit Gasoline	57.4	18.7	1.024	2.01
FET	Cutlass Diesel	662.4	134.2	8.541	1.94
	Cutlass Gasoline	943.6	160.9	12.167	17.31
	Rabbit Diesel	303.6	105.2	3.914	1.52
	Rabbit Gasoline	231.0	61.8	2.979	6.64

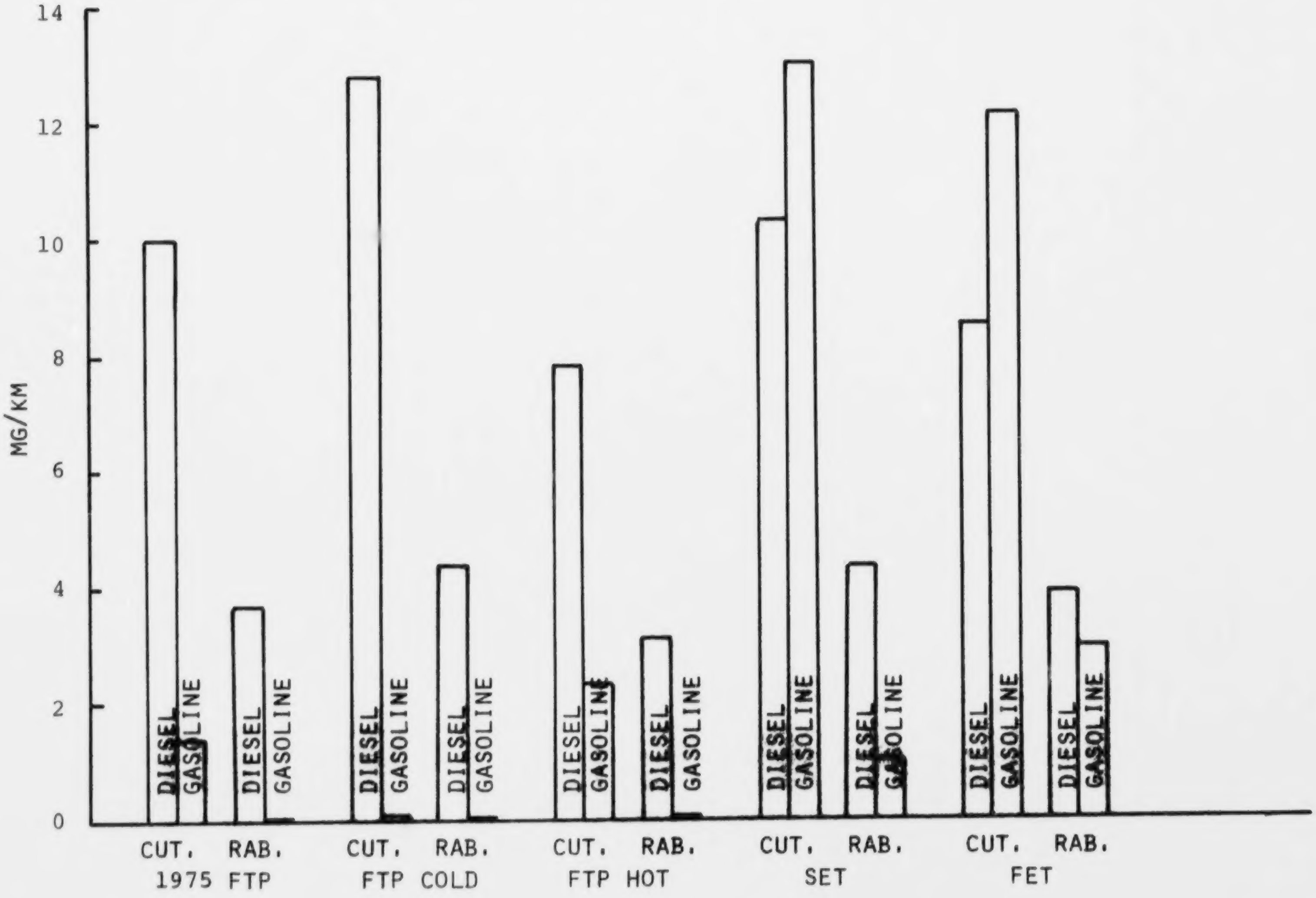


Figure 43. Sulfate Emission Rates for Diesel- and Gasoline-Powered Passenger Cars

very little sulfate from the gasoline cars compared to the Diesel. During the sulfate emission test (SET), the Cutlass gasoline car sulfate rate increased markedly from the FTP hot run (which, in turn, was higher than the FTP cold). This behavior of sulfate from gasoline-powered oxidation-catalyst-equipped cars is not uncommon and has been demonstrated in a number of studies. References 66 and 67 give typical data for comparison.

The gasoline-powered Rabbit, which also had an oxidation catalyst, emitted more sulfate during the SET and more yet during the FET. Sulfate during the FTP was negligible. In both gasoline-fueled cars, the low FTP values are commonly attributed to "storage" of the sulfate in the exhaust system. Both Diesel cars seemed less influenced by the type cycle with no indication of sulfate "storage" during the FTP operation.

Based on the SwRI SET test, the Diesel Rabbit produced 4.3 times the sulfate of the gasoline Rabbit, and the experimental Diesel Cutlass emitted 0.8 or 80 percent of the gasoline sulfate rate. Comparing the two Diesels, the Cutlass emitted from 2.2 to 2.8 times the sulfate as the Rabbit. One reason for this is the higher fuel consumption of the larger, heavier Cutlass versus the Rabbit.

Another way to consider the sulfate results is in terms of percent of fuel sulfur converted to sulfate. Table 65 is a comparison of this data for both cars. While the Diesel conversion percentages all range from 1 to 2 percent of the fuel consumed, the gasoline-powered vehicles ranged from less than 0.1 percent during the cold start to as high as 17.3 percent during the FET test of the Cutlass. This car, equipped with catalyst but without air pump, emitted far greater sulfate levels than similar size non-air catalyst cars previously tested.(66) The SET value of 16 percent is on the order of that from an air pump catalyst-equipped car. The Volkswagen Rabbit, on the

TABLE 65. COMPARISON OF PERCENT SULFUR IN FUEL CONVERTED TO SULFATE BY GASOLINE AND DIESEL CARS

Test	Cutlass, %			Rabbit, %		
	Diesel	Gasoline	Ratio[a]	Diesel	Gasoline	Ratio[a]
1975 FTP	1.57	1.589	1.0	1.24	0.062	20.0
FTP Cold	1.91	0.072	26.5	1.34	0.038	35.3
FTP Hot	1.32	2.404	0.5	1.02	0.076	13.4
SET	1.30	15.999	0.1	1.66	2.009	0.8
FET	1.94	17.306	0.1	1.52	6.644	0.2

(a) ratio = $\frac{\text{Diesel}}{\text{gasoline}}$

other hand, had 2 percent conversion during the SET, a reasonable value for a catalyst non-air equipped vehicle.

Based on the SET results, it may be concluded that the experimental Diesel emitted slightly less sulfate than the gasoline-powered Cutlass, 10.3 versus 13.0 mg/km, while the Diesel-powered Rabbit emitted far more than the gasoline Rabbit, 4.4 versus 1.0 mg/km. These comparisons are based on a sample of only four cars using "National Average" fuel sulfur levels and all other test aspects identical.

For additional individual test results, please refer to Appendix Tables F-4 through F-7. Each table lists the emission rates for a given car and lists percent sulfur converted to sulfate. This data indicates the run-to-run repeatability of the two Diesels to be quite satisfactory.

E. Carbon-Hydrogen-Nitrogen

The percent carbon (C), hydrogen (H), and nitrogen (N) in the particulate sample collected on the glass fiber filter was analyzed by ASTM method D-3178. The results are listed on Table 66 and show little difference between the two gasoline cars. A substantial difference is shown between Diesel- and gasoline-powered cars, however. Carbon content was expected to be much higher, but the major differences in hydrogen and nitrogen will require further work to fully explain. The different boiling ranges of the fuels could likely be a major reason for the hydrogen differences, and the lack of carbon on the filter may further explain the very low hydrogen values. Possibly, the difference in fuels plus the lack of carbon on the filter is the reason for the lower nitrogen values; however, this is speculation.

TABLE 66. CARBON, HYDROGEN, AND NITROGEN CONTENT
OF FILTER PARTICULATE, PERCENT BY WEIGHT

		Cutlass		Rabbit	
Element	Cycle	Diesel	Gasoline	Diesel	Gasoline
C	FTP Cold	76.83	0.070	78.33	0.087
	FTP Hot	82.07	0.080	73.19	0.093
	SET	78.49	0.076	73.22	0.078
	FET	80.95	0.081	77.04	0.081
H	FTP Cold	3.33	0.051	4.29	0.049
	FTP Hot	3.79	0.052	4.80	0.050
	SET	4.00	0.058	4.43	0.045
	FET	4.89	0.055	3.85	0.049
N	FTP Cold	0.54	0.0076	0.60	0.0064
	FTP Hot	0.54	0.0084	0.66	0.0076
	SET	0.59	0.017	0.51	0.0072
	FET	0.68	0.010	0.45	0.0075

F. Metals

The particulate matter collected on the 47 mm Fluoropore plastic filters were analyzed by X-ray fluorescence to determine the presence and amount of lead, manganese, mercury, phosphorus, sodium, zinc, copper, calcium, vanadium, iron, aluminum, silica, nickel, tin, and sulfur. Table 67 shows that only iron, zinc, aluminum, and sulfur were detectable by the method used. Except for sulfur, the results were not consistent for either Diesel or gasoline-fueled cars. Some iron was found in all Rabbit Diesel filters. Note the essential absence of sulfur (by this measurement method) from both gasoline vehicles during the FTP cycle and its apparent purge and collection during the SET and FET. This is in qualitative agreement with the data in Table 64 and graphed on Figure 43.

TABLE 67. METAL CONTENT OF PARTICULATE SAMPLES
(PERCENT OF PARTICULATE)

		Cutlass		Rabbit	
Element	Cycle	Diesel	Gasoline	Diesel	Gasoline
Iron	FTP Cold	0.35	12.4	0.7	----
	FTP Hot	----[a]	----	1.2	----
	SET	----	----	0.46	----
	FET	----	----	0.26	----
Zinc	FTP Cold	----	11.6	----	----
	FTP Hot	----	----	----	----
	SET	----	----	----	----
	FET	----	----	----	----
Aluminum	FTP Cold	----	----	----	----
	FTP Hot	----	----	0.34	----
	SET	----	----	----	----
	FET	----	----	----	----
Sulfur	FTP Cold	1.2	----	1.1	----
	FTP Hot	0.83	6.2	1.2	----
	SET	1.4	30.6	1.6	9.0
	FET	1.4	28.0	1.3	18.3

(a) below detectable limit

G. Odor Ratings and Related Analysis

This section discusses the odor ratings by trained panel and DOAS as well as the supplemental analyses obtained at the same time odor was measured.

1. Odor Ratings by Trained Panel

Table 68 contains a summary listing of the odor ratings for both Diesel-powered cars. The evaluations were made at both 100:1 and at 550:1 dilution ratios. As expected, the odor was always lower at the higher dilution level.

A direct comparison between the two Diesel cars during steady state is not possible since the Volkswagen Rabbit mid and high loads were half and maximum power (at 90.1 km/hr high gear, 3360 rpm, and at 53.1 km/hr high gear, 2020 rpm). The automatic transmission in the Cutlass severely limited the power level at both 90.1 and 53.1 km/hr due to excessive slip as power level was increased. Accordingly, power levels were necessarily limited to that capable by the vehicle.

Figures 44 and 45 are bar graph and "D" versus power plots of the Appendix F data. The "D" odor intensity generally increased with power level. Little change with power was noted at 550:1 for the Cutlass Diesel. The bar graphs are a summation of each odor rating which gives about equal importance to the "D" intensity value and the sum of the four quality ratings.

Table 69 is an overall summary of the two Diesel cars by type of operation as well as dilution ratio. Both cars are found to have about the same exhaust odor intensity with the only notable difference being the transients in which the Rabbit produced a higher "D" intensity than the Cutlass experimental Diesel, on the order of "D"-3.5 versus "D"-2.7 at 100:1 dilution. This difference was not as detectable at the higher 550:1 dilution level. If 100:1 is taken to be the minimum dilution level of Diesel exhaust, then both Diesel cars had odor levels that would be easily noticed by most people. The "D"-3 level, from the odor opinion study, was found objectionable to 77 percent of those surveyed.(24,25)

Appendix Tables F-8 through F-15 list the detailed rating summaries for further study. This data lists the run-to-run results for the steady states, in triplicate, and the transient tests, replicated four times.

TABLE 69. ROUGH COMPARISON OF LIGHT-DUTY VEHICLE "D" ODOR RATINGS

Diesel Car	Dilution Ratio	Six Steady States	Idle	Cold Start	Three Transients	All Eleven Conditions
Oldsmobile	100:1	2.9	3.4	4.0	2.7	3.0
	550:1	1.0	0.8	2.0	1.1	1.1
	Difference	1.9	2.6	2.0	1.6	1.9
Volkswagen	100:1	3.1	3.6	4.0	3.5	3.3
	550:1	1.1	1.2	2.4	1.0	1.2
	Difference	2.0	2.4	1.6	2.5	2.1

TABLE 68. LISTING OF AVERAGE ODOR PANEL RATINGS FOR DIESEL-POWERED PASSENGER CARS

			Q/I Odor Rating				
Operating Condition	Diesel Car	Dilution Ratio	"D" Composite	"B" Burnt	"O" Oily	"A" Aromatic	"P" Pungent
		Steady State Results					
Inter. Speed 0 Load	Cutlass	100:1	2.5	1.0	1.0	0.6	0.3
		550:1	1.1	0.8	0.2	0.3	0
	Rabbit	100:1	2.8	1.1	0.9	0.7	0.5
		550:1	0.9	0.7	0.3	0.1	0
Inter. Speed Mid Load	Cutlass	100:1	2.7	1.0	1.0	0.5	0.6
		550:1	1.0	0.7	0.3	0.2	0.1
	Rabbit	100:1	2.8	1.1	1.0	0.6	0.6
		550:1	1.1	0.7	0.3	0.2	0.1
Inter. Speed High Load	Cutlass	100:1	2.8	1.0	1.0	0.6	0.6
		550:1	0.8	0.7	0.2	0.2	0
	Rabbit	100:1	3.3	1.1	1.0	0.6	0.8
		550:1	1.3	0.7	0.4	0.4	0.1
High Speed 0 Load	Cutlass	100:1	3.0	1.0	1.0	0.8	0.7
		550:1	0.9	0.8	0.3	0.2	0
	Rabbit	100:1	2.3	1.0	1.0	0.4	0.3
		550:1	0.9	0.6	0.2	0.2	0.1
High Speed Mid Load	Cutlass	100:1	3.2	1.1	1.0	0.6	0.7
		550:1	1.0	0.7	0.2	0.3	0
	Rabbit	100:1	3.5	1.2	1.0	0.6	0.9
		550:1	0.9	0.6	0.5	0.1	0
High Speed High Load	Cutlass	100:1	3.3	1.1	1.0	0.7	0.7
		550:1	1.0	0.8	0.3	0.2	0.1
	Rabbit	100:1	3.8	1.2	1.1	0.8	0.9
		550:1	1.3	0.9	0.5	0.2	0
Idle	Cutlass	100:1	3.4	1.2	1.0	0.8	0.6
		550:1	0.8	0.6	0.3	0.2	0
	Rabbit	100:1	3.6	1.1	1.0	0.8	0.8
		550:1	1.2	0.9	0.3	0.2	0.1
		Transient Results					
Idle-Acceleration	Cutlass	100:1	2.6	1.0	0.9	0.7	0.5
		550:1	1.0	0.8	0.4	0.3	0.1
	Rabbit	100:1	3.5	1.2	1.0	0.7	1.0
		550:1	0.8	0.7	0.3	0.3	0.1
Acceleration	Cutlass	100:1	2.8	1.0	1.0	0.7	0.5
		550:1	1.0	0.8	0.3	0.2	0
	Rabbit	100:1	3.7	1.3	1.0	0.8	0.9
		550:1	1.3	0.9	0.5	0.3	0.2
Deceleration	Cutlass	100:1	2.8	1.0	1.0	0.6	0.6
		550:1	1.3	0.9	0.5	0.2	0.1
	Rabbit	100:1	3.3	1.1	1.0	0.9	0.7
		550:1	0.9	0.8	0.3	0.3	0.1
Cold Start	Cutlass	100:1	4.0	1.4	1.0	0.9	0.8
		550:1	2.0	1.0	1.0	0.2	0.2
	Rabbit	100:1	4.0	1.3	1.0	0.9	0.9
		550:1	2.4	1.0	1.0	0.4	0.3

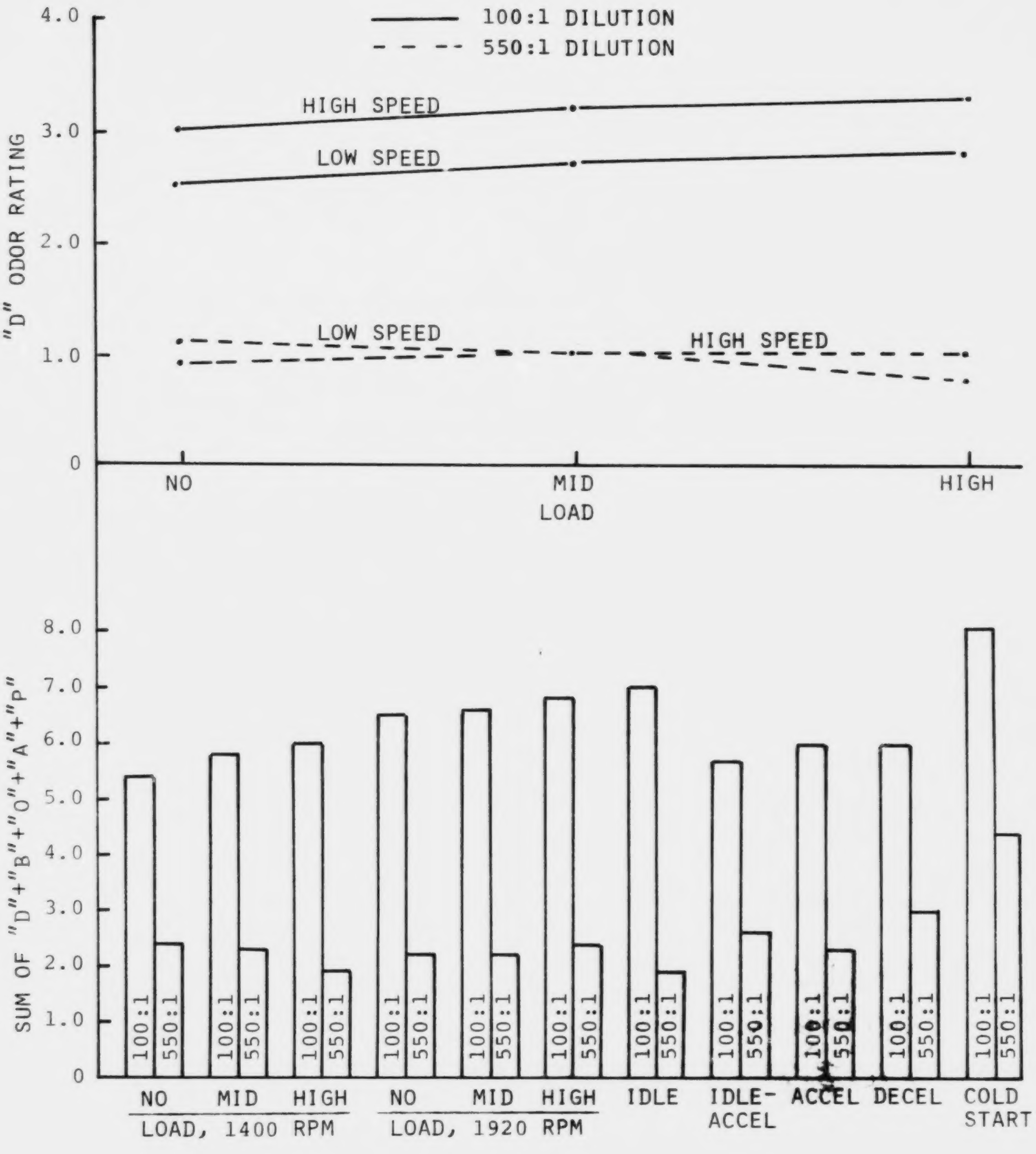


Figure 44. Average Odor Ratings for Cutlass Diesel Car

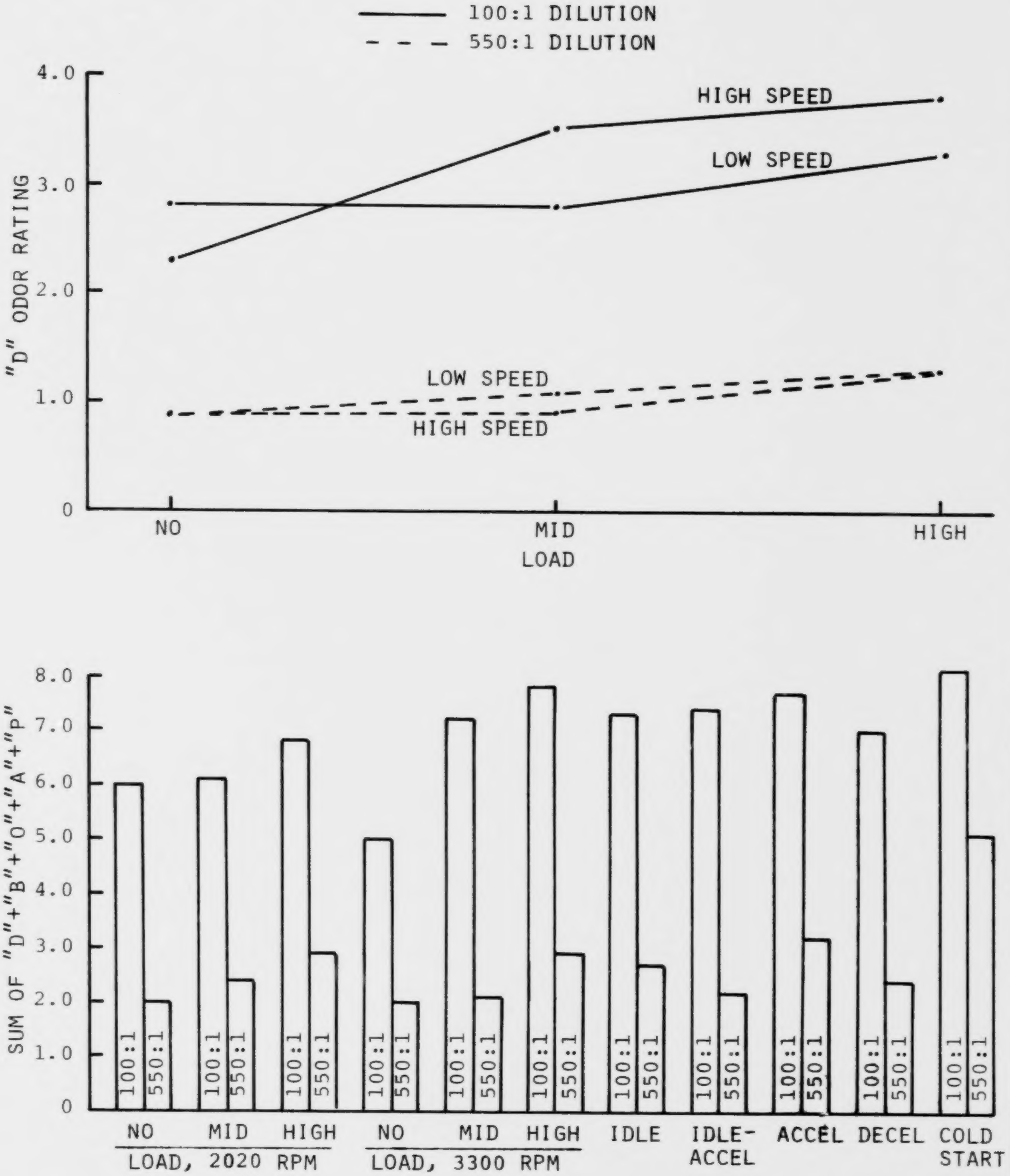


Figure 45. Average Odor Ratings for Rabbit Diesel Car

2. Odor by DOAS

Listed in Table 70 are the average values obtained by the DOAS simultaneously with the odor panel ratings. Figure 46 is a plot of TIA versus "D" level for both cars. It is interesting to note the clustering of data at the 100:1 and at the 550:1 dilution levels. At 550:1, all the "D" levels were less than 1.3, which is a relatively low and light odor strength. There appears to be some correlation with TIA at the usual 100:1 dilution level.

An attempt was made to obtain DOAS values during various transient driving cycles to see if there might be a correlation with the steady-state data. Table 70 also lists the DOAS values for both Diesel cars, and Figure 47 illustrates the TIA values for the FTP, SET and FET cycles. These results would predict the odor from both cars during the transient cycles to be essentially the same, with the higher duty cycle FET odor the highest. Only with the Rabbit Diesel was there a noticeable upward trend of odor with power (top half of Figure 45).

3. Related Gaseous Emissions

Gaseous emissions, measured at the same time as the steady-state odor tests, are summarized in Table 71. The averages thus listed are averages of the replicate odor test days. These day-to-day summaries as well as individual run-to-run emissions for each day for both Diesel cars are included as Tables F-16 through F-23. Also listed on these tables are the DOAS results in terms of LCA, LCO and TIA values.

H. Aldehydes

Table 72 lists the various aldehyde results during the seven steady-state and three transient cycles. Looking first at formaldehyde, the simplest and most prevalent of the partially oxygenated compounds listed, the Cutlass experimental Diesel was higher in raw exhaust concentration than the Rabbit Diesel. The same general behavior was noted for acetaldehyde and acetone. The GLC separation lumps together in the acetone value not only acetone, but acrolein and propanal. Isobutanal and benzaldehyde values were sometimes lower and sometimes higher with one Diesel relative to the other, and no overall trend was evident by operating condition or vehicle.

The transient cycle data listed on the bottom of Table 72 is illustrated on Figure 48. The ordinate is the sum of the individual aldehydes measured in mg/km. In this way, a rough general comparison by car and test cycle can be made. The experimental Diesel Cutlass produced more aldehydes than the gasoline Cutlass regardless of test cycle.

The Diesel and gasoline Rabbits produced nearly identical amounts, although a reversal in behavior occurred between the cold and hot FTP's. The experimental Diesel Cutlass produced more aldehydes than the Rabbit Diesel, on the order of two to three times, depending on cycle. Some of this difference is attributed to the difference in vehicle size, weight, power produced, and fuel consumed.

TABLE 70. DOAS RESULTS OF DIESEL CARS DURING STEADY-STATE ODOR TESTS AND TRANSIENT CYCLES

Condition/Cycle	Vehicle	LCA, µg/ℓ	LCO, µg/ℓ	TIA
		STEADY-STATE		
Intermediate Speed, No Load	Cutlass	14.0	6.0	1.8
	Rabbit	5.3	2.6	1.4
Intermediate Speed, Mid Load	Cutlass	16.1	6.0	1.8
	Rabbit	14.6	5.1	1.8
Intermediate Speed, High Load	Cutlass	14.5	5.6	1.8
	Rabbit	15.3	6.2	1.8
High Speed, No Load	Cutlass	15.4	6.5	1.8
	Rabbit	7.6	2.8	1.5
High Speed, Mid Load	Cutlass	15.4	5.4	1.6
	Rabbit	22.9	6.8	1.9
High Speed, High Load	Cutlass	12.2	7.1	1.9
	Rabbit	23.5	10.7	2.0
Idle	Cutlass	18.4	4.9	1.6
	Rabbit	9.3	3.6	1.6
		TRANSIENT CYCLES		
FTP Cycle	Cutlass	6.1	1.8	1.2
	Rabbit	3.8	1.2	1.1
SET Cycle	Cutlass	5.5	1.7	1.2
	Rabbit	3.3	1.1	1.0
FET Cycle	Cutlass	7.8	2.6	1.4
	Rabbit	4.9	1.5	1.2

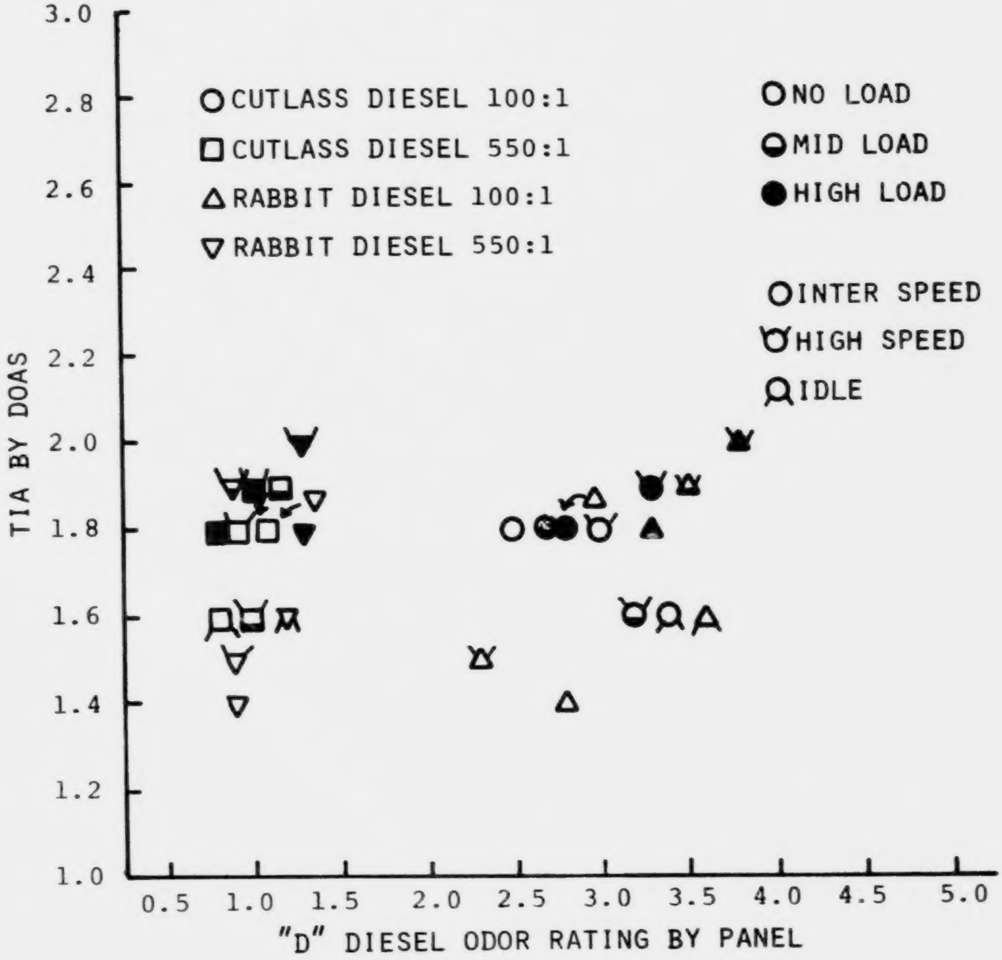


Figure 46. TIA by DOAS Versus "D" Odor Rating by Trained Panel for Two Diesel Cars at Two Dilution Levels

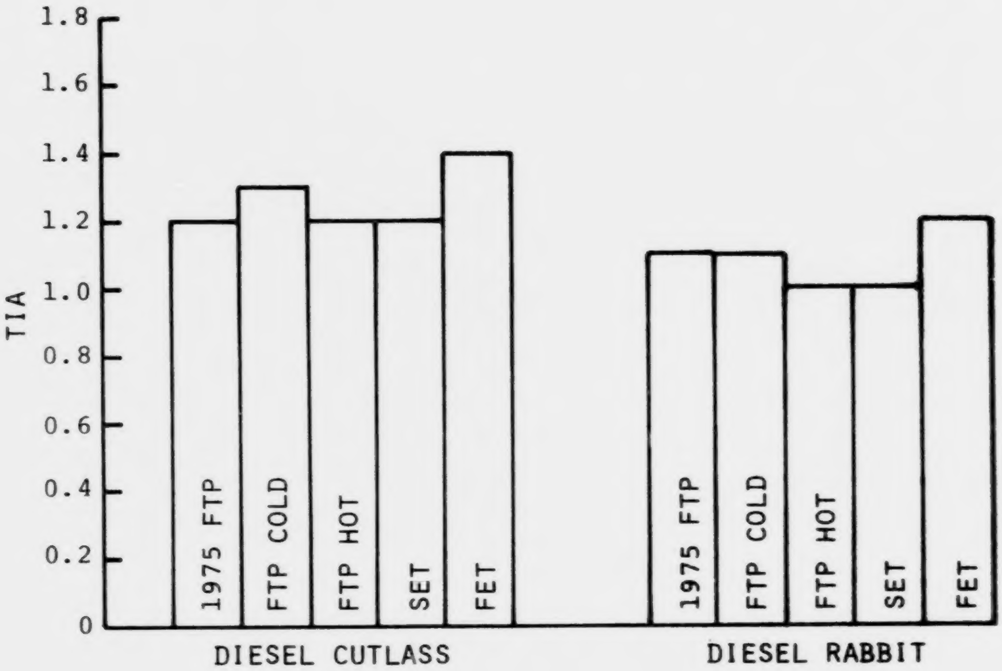


Figure 47. TIA of Various Driving Cycles for Diesel-Powered Passenger Cars

TABLE 71. EXHAUST ANALYSES OF DIESEL CARS DURING STEADY-STATE ODOR TESTS

Condition	Vehicle	HC ppmC	CO ppm	NO-NDIR ppm	NO-CL ppm	NO_x-CL ppm	CO_2 %
Intermediate Speed, No Load	Cutlass	139	319	84	79	79	2.0
	Rabbit	66	257	69	65	65	2.0
Intermediate Speed, Mid Load	Cutlass	102	299	198	175	175	4.7
	Rabbit	69	181	298	270	270	6.4
Intermediate Speed, High Load	Cutlass	91	316	251	222	222	7.0
	Rabbit	87	344	314	296	296	12.5
High Speed, No Load	Cutlass	147	335	88	79	79	2.3
	Rabbit	52	231	115	102	102	2.3
High Speed, Mid Load	Cutlass	92	308	263	231	231	6.5
	Rabbit	129	336	400	373	373	7.5
High Speed, High Load	Cutlass	85	548	290	263	263	10.6
	Rabbit	93	2027	348	324	322	13.9
Idle	Cutlass	284	521	58	55	55	2.4
	Rabbit	184	392	102	91	91	2.1

TABLE 72. ALDEHYDES OBTAINED DURING STEADY-STATE ODOR TESTS AND TRANSIENT CYCLES

Condition/Cycle	Vehicle	Form-aldehyde	Acet-aldehyde	Ace-tone	Iso-butanal	Crot-onal	Hex-anal	Benz-aldehyde
		STEADY-STATES, $\mu g/m^3$						
Intermediate Speed, No Load	Cutlass Diesel	8990	2046	1010	----	793	--	591
	Rabbit Diesel	5922	1613	1200	969	908	--	622
Intermediate Speed, Mid Load	Cutlass Diesel	3005	1656	754	----	447	92	497
	Rabbit Diesel	1726	777	523	582	460	--	----
Intermediate Speed, High Load	Cutlass Diesel	1407	1126	1333	----	435	--	279
	Rabbit Diesel	2028	1800	719	244	1052	--	1495
High Speed, No Load	Cutlass Diesel	8581	2543	1320	330	631	54	465
	Rabbit Diesel	1653	433	566	621	495	--	178
High Speed, Mid Load	Cutlass Diesel	2506	1854	1642	----	1405	--	377
	Rabbit Diesel	2137	636	443	----	616	--	1490
High Speed, High Load	Cutlass Diesel	3174	2056	916	----	850	--	430
	Rabbit Diesel	1241	1035	537	18	(a)	--	----
Idle	Cutlass Diesel	12051	4071	1346	----	924	--	555
	Rabbit Diesel	12325	3323	1891	1181	1355	--	190
		TRANSIENT CYCLES, mg/km						
1975 FTP	Cutlass Diesel	15.8	6.5	35.7	18.5	4.2	---	1.8
	Cutlass Gasoline	2.6	0.4	----	3.8	7.2	---	---
	Rabbit Diesel	16.0	5.0	2.6	16.0	----	---	---
	Rabbit Gasoline	0.4	---	----	2.6	32.1	---	2.7
FTP Cold	Cutlass Diesel	15.0	7.6	44.1	19.3	6.2	---	2.2
	Cutlass Gasoline	3.7	0.8	----	2.6	11.2	---	---
	Rabbit Diesel	26.3	8.0	5.6	27.0	----	---	2.4
	Rabbit Gasoline	0.2	0.2	0.3	2.3	21.0	---	0.8
FTP Hot	Cutlass Diesel	16.5	5.6	29.5	18.0	2.7	---	1.5
	Cutlass Gasoline	1.8	0.1	0.1	4.6	4.1	0.9	7.4
	Rabbit Diesel	8.1	2.8	0.3	7.8	----	---	---
	Rabbit Gasoline	0.5	---	----	2.8	40.5	---	4.1
SET	Cutlass Diesel	12.3	6.3	5.1	10.4	2.4	---	1.1
	Cutlass Gasoline	1.3	---	----	1.8	0.6	---	5.3
	Rabbit Diesel	6.0	1.5	1.0	1.9	----	---	---
	Rabbit Gasoline	0.3	---	----	2.1	4.3	---	2.2
FET	Cutlass Diesel	8.2	3.0	3.3	8.9	----	---	---
	Cutlass Gasoline	1.6	---	0.5	6.5	1.2	---	0.8
	Rabbit Diesel	4.3	1.1	2.7	3.3	----	---	---
	Rabbit Gasoline	0.5	---	----	6.4	3.7	---	1.0

(a) sample contaminated

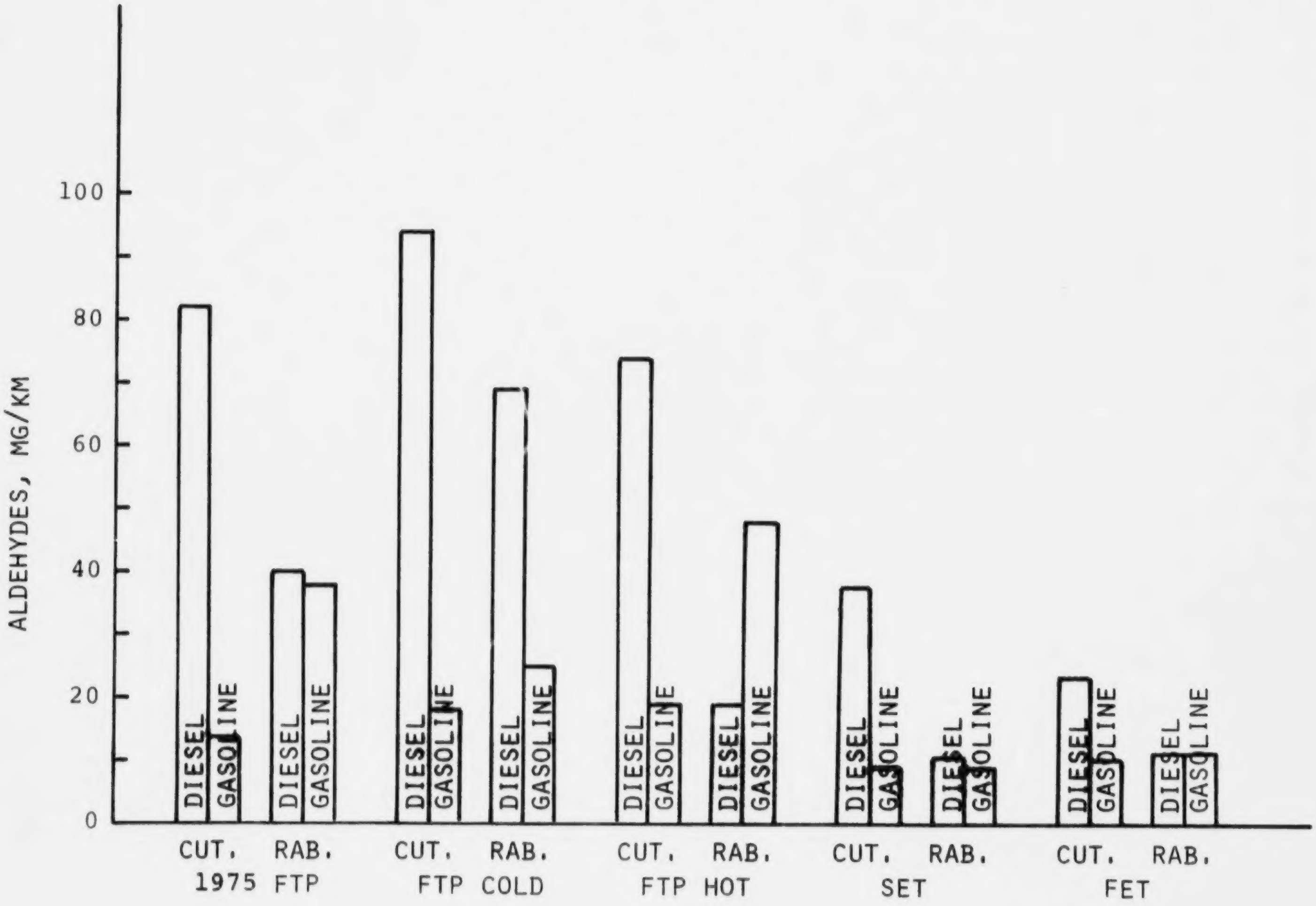


Figure 48. Aldehyde Emission Rates for Diesel- and Gasoline-Powered Passenger Cars

I. Specific Hydrocarbons

Both steady-state and transient cycle results are listed in Table 73. One item of importance from this data is methane as a percent of the HC measured by FID. Table 74 lists the methane and FID HC values from Tables 73 and 71, respectively. Methane ranged from about 1 to 4 percent of the FID hydrocarbons for both Diesel cars.

This range holds well for the transient cycle results listed at the bottom of Table 74. The two gasoline cars, however, had methane fractions of the exhaust hydrocarbons on the order of 14 to 58 percent. The highest percentages were for the Rabbit gasoline ranging from 24 to 58 percent. The Cutlass gasoline ranged from 14 to 31 percent. Methane is generally considered nonreactive in photochemical reactions; therefore, it is helpful to know how much of the exhaust hydrocarbons are methane. The exhaust from the two Diesels tested were a nominal 3±2 percent methane, while the two gasoline cars tested had a nominal 35±20 percent methane.

Benzene was always higher, by about 30 percent, from the Oldsmobile 350 Diesel than the Rabbit Diesel except at high speed and load. During transient testing, the difference in the two Diesel cars' benzene emissions was greater, about 50 percent. Compared to their gasoline counterparts, the Oldsmobile Diesel was much higher, about two times the gasoline Oldsmobile on the 1975 FTP. The Rabbit Diesel was, over all three cycles, about the same as the gasoline Rabbit.

J. Polynuclear Aromatics

BaP was measured as an indicator of the polynuclear aromatic content of the vehicle exhaust. The thin layer chromatography method described earlier (16, 62) was used. An 8 x 10 size fiberglass filter was used to collect sufficient particulate for BaP analysis.

Table 75 lists the emission rate of BaP for all four cars. In the case of the two Diesel cars, emission rates of from about 2 to 5 (Cutlass Diesel) and 1 to 5 (Rabbit Diesel) in terms of μg/km of BaP were found. The method depends on the trapping of the BaP from the diluted exhaust on the particulate coated glass fiber filter.

When this simple and rapid dilution tunnel method was used with the gasoline exhaust, little particulate was collected, just as in the case of the 47 mm filters. Recall that the two gasoline vehicles emitted on the order of 1/50 to 1/80 the particulate of the Diesel cars and that which was collected had a negligible percentage of carbon per Table 66. In discussions with Dr. Ronald Bradow of EPA Environmental Sciences Research Laboratories, it was mentioned that BaP collection on fiberglass filters by the tunnel method may be dependent on the carbon particulate. In the case of the Diesel, it is thought that the carbon acts as the collecting media and this may explain why BaP values from the two gasoline-powered cars were below detectable limits in all but two instances.

TABLE 73. DETAILED HC ANALYSIS DURING STEADY-STATE ODOR TESTS AND TRANSIENT CYCLES

Condition/Cycle	Vehicle	Meth-ane	Eth-ane	Acety-lene	Prop-ane	Benz-ene	Ethy-lene	Propy-lene	Tolu-ene
		STEADY-STATES, ppm C							
Intermediate Speed, No Load	Cutlass Diesel	4.2	1.1	2.3	0	2.6	17.4	5.3	0
	Rabbit Diesel	0.6	0.3	0.8	0	0.9	13.4	4.2	0
Intermediate Speed, Mid Load	Cutlass Diesel	4.0	1.1	2.2	0	3.1	15.3	4.3	0
	Rabbit Diesel	2.2	0.5	1.1	0	2.3	12.5	4.0	0
Intermediate Speed, High Load	Cutlass Diesel	3.3	0.9	2.1	0	3.6	15.0	4.0	0
	Rabbit Diesel	3.3	0.7	1.5	0	3.4	20.1	6.1	0.5
High Speed, No Load	Cutlass Diesel	4.5	1.0	2.1	0	2.3	16.9	5.9	0
	Rabbit Diesel	0.9	0.4	0.8	0	0.9	9.5	2.8	0
High Speed, Mid Load	Cutlass Diesel	2.5	0.7	2.0	0	2.4	14.8	4.1	0
	Rabbit Diesel	2.2	3.2	6.3	0	8.3	45.9	9.3	1.4
High Speed, High Load	Cutlass Diesel	1.0	0.4	2.2	0	3.9	19.3	4.6	0
	Rabbit Diesel	1.8	1.6	5.8	0	7.7	34.1	5.3	0.4
Idle	Cutlass Diesel	10.5	2.9	7.0	0	7.7	37.4	10.9	1.8
	Rabbit Diesel	2.3	0.7	1.5	0	1.9	26.1	8.1	0.7
		TRANSIENT CYCLES, mg/km							
1975 FTP	Cutlass Diesel	12.7	4.2	5.3	0.1	11.6	49.2	17.1	2.6
	Cutlass Gasoline	29.5	14.8	1.1	0	5.6	18.2	8.2	13.9
	Rabbit Diesel	6.7	0.9	1.5	0	5.1	28.1	9.6	0.6
	Rabbit Gasoline	33.0	6.4	2.6	0	9.1	15.2	4.0	12.3
SET	Cutlass Diesel	5.1	1.7	2.6	0	6.4	28.5	8.9	0
	Cutlass Gasoline	24.2	9.2	0	0	2.7	6.3	0	2.4
	Rabbit Diesel	3.3	0.4	1.2	0	2.9	15.3	4.5	1.6
	Rabbit Gasoline	17.4	2.4	0	0	0	1.1	0	1.2
FET	Cutlass Diesel	3.4	1.3	1.9	0	4.9	21.8	6.5	0.9
	Cutlass Gasoline	18.4	6.7	0	0	0.8	2.9	0	1.4
	Rabbit Diesel	4.7	0.6	1.7	0	3.2	15.1	4.5	0
	Rabbit Gasoline	14.6	0	0	0	0.4	2.0	0	0.9

TABLE 74. METHANE FRACTION OF EXHAUST HC DURING STEADY-STATE ODOR TESTS AND TRANSIENT CYCLES

Condition/Cycle	Vehicle	Methane	HC	% Methane
		STEADY-STATE		
Intermediate Speed, No Load	Cutlass Diesel	4.2 ppmC	139 ppmC	3.0
	Rabbit Diesel	0.6	66	0.9
Intermediate Speed, Mid Load	Cutlass Diesel	4.0	103	3.9
	Rabbit Diesel	2.2	69	3.2
Intermediate Speed, High Load	Cutlass Diesel	3.3	91	3.6
	Rabbit Diesel	3.3	87	3.8
High Speed, No Load	Cutlass Diesel	4.5	147	3.1
	Rabbit Diesel	0.9	52	1.7
High Speed, Mid Load	Cutlass Diesel	2.5	92	2.7
	Rabbit Diesel	2.2	129	1.7
High Speed, High Load	Cutlass Diesel	1.0	85	1.2
	Rabbit Diesel	1.8	93	1.9
Idle	Cutlass Diesel	10.5	284	3.7
	Rabbit Diesel	2.3	184	1.3
		TRANSIENT CYCLES		
1975 FTP	Cutlass Diesel	12.7 mg/km	0.47 g/km	2.7
	Cutlass Gasoline	29.5	0.21	14.0
	Rabbit Diesel	6.7	0.23	2.9
	Rabbit Gasoline	33.0	0.14	23.6
SET	Cutlass Diesel	5.1	0.27	1.9
	Cutlass Gasoline	24.2	0 08	30.3
	Rabbit Diesel	3.3	0.09	3.7
	Rabbit Gasoline	17.4	0.03	58.0
FET	Cutlass Diesel	3.4	0 21	1.6
	Cutlass Gasoline	18.4	0.06	30.7
	Rabbit Diesel	4.7	0.08	5.9
	Rabbit Gasoline	14.6	0.03	48.7

TABLE 75. BaP CONTENT IN DIESEL CAR PARTICULATE MATTER

Vehicle	Test	BaP Emission Rate mg/hr	 mg/kg fuel	 µg/km	Organic Solubles % of Particulate
Cutlass Diesel	1975 FTP	0.1427	0.0507	4.540	13.3
	FTP Cold	0.1170	0.0383	3.723	12.4
	FTP Hot	0.1621	0.0600	5.157	14.0
	SET	0.1385	0.0334	2.471	18.2
	FET	0.1480	0.0300	1.908	19.0
Cutlass Gasoline(a)	FET	0.013	0.0022	0.168	10.7
Rabbit Diesel	1975 FTP	0.0839	0.0569	2.674	21.4
	FTP Cold	0.1540	0.1030	4.914	20.2
	FTP Hot	0.0310	0.0221	0.985	22.3
	SET	0.0865	0.0403	1.540	15.4
	FET	0.1170	0.0406	1.512	13.0
Rabbit Gasoline(a)	FTP Hot	0.0053	0.0024	0.168	42.3

(a) BaP values are considered conservative and should be used with caution due to inadequacies of sampling method.

BaP is present in gasoline engine exhaust and can be collected by methods developed earlier.(68,69) The intent of this effort was to obtain data on both types of cars by the same method, and the methods used by Exxon were beyond the scope of the effort. Thus, it may be concluded that the relatively simple and rapid dilution tunnel filter method for collecting BaP and presumably other polynuclear aromatic compounds has not yet been refined enough to be used routinely for gasoline engine exhaust. Suitable filter media will have to be developed.

Of some interest in Table 75 is the percent organic solubles in the particulate. The values for the two Diesels ranged from 12 to 22 percent, indicating a relatively dry exhaust particulate, free from excessive unburned fuel, oil, and aerosol-like matter that can (with some designs of Diesels) increase the organic soluble fraction up to as high as 50 percent.(31) Presumably, the remainder of the particulate is inorganic in nature and is carbonaceous or some metallic compound.

K. Noise

Table 76 is a summary of the sound level measurements. The SAE driveby exterior ratings show the Diesel Cutlass to be 6 dBA higher than the gasoline-powered Cutlass, while the Volkswagen Rabbit had the same dBA measurement for both powerplants. Interior measurements were slightly higher with the Diesel for both makes during the SAE acceleration.

The exterior driveby at a constant 48.3 km/hr (30 mph) showed slightly higher noise (exterior and interior) for the experimental Cutlass, while the opposite trend was found for the gasoline Rabbit. Idle noise levels were noticeably higher with the Diesel Cutlass and only slightly higher with the Diesel Rabbit. Tables F-24 through F-27 are the detailed sound level measurements from which the summary data on Table 76 are derived.

L. Performance

Table 77 is a listing of the wide-open throttle maximum acceleration times for the four cars. The acceleration performance of the Rabbit powered by the Diesel engine was poorer than that of its gasoline counterpart. The times to accelerate from 0 to 64.6, from 0 to 96.5, and from 32.2 to 96.5 km/hr were increased by 20 to 27 percent with the lower powered Diesel engine in the Rabbit. The Cutlass suffered less acceleration penalty with the Diesel, namely, 7 to 11 percent. Note that the comparison was between the 260 CID V-8 gasoline-powered Cutlass and the experimental 350 CID V-8 Diesel Cutlass. Using the smaller gasoline engine option for the Cutlass is probably the reason the increase in acceleration times was no greater than about 10 percent.

TABLE 76. SUMMARY OF SOUND LEVEL MEASUREMENTS - dBA SCALE

	Cutlass		Rabbit	
	Gasoline	Diesel	Gasoline	Diesel
SAE J986a Accel Driveby Exterior	68.8(c)	73.8(c)	71.0	71.5
Interior Blower On(a)	73.2(c)	74.2(c)	78.2	80.0
Off	68.8(c)	70.5(c)	76.5	79
48.3 km/hr Driveby Exterior	58.8	61.2	60.5	58.5
Interior Blower On(a)	71.5	72.2	73.5	71.8
Off	60.5	64.0	70.5	68.0
Engine Idle Exterior(b)	64.5	70.0	65.0(d) 72.5(e)	67.0
Interior Blower On(a)	71.5	71.0	69.5	69.5
Off	48.5	51.5	58.0	62.5

(a) windows up, fresh air blower on high
(b) at 3.05 m
(c) accel in first gear
(d) electric, radiator, cooling fan off
(e) electric, radiator, cooling fan on

TABLE 77. AVERAGE ACCELERATION TIMES FOR DIESEL- AND GASOLINE-POWERED PASSENGER CARS

Vehicle	0-64.4 km/hr[a] time, sec	0-96.5 km/hr[b] time, sec	32.2-96.5 km/hr[c] time, sec
Rabbit Diesel	7.58	15.80	12.83
Rabbit Gasoline	6.33	12.48	10.45
Increase, %[d]	19.7	26.6	22.8
Cutlass Diesel	8.98	17.70	14.53
Cutlass Gasoline	8.08	16.13	13.53
Increase, %[d]	11.1	9.7	7.4

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[a] 0-40 mph

[b] 0-60 mph

[c] 20-60 mph

[d] $\frac{\text{Diesel time - gasoline time}}{\text{Diesel time}} \times 100\%$

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APPENDIX A

EXPERIMENTAL 23-MODE TEST PROCEDURE FOR ENGINES IN HEAVY-DUTY MOTOR VEHICLES

are weighted and used to calculate the grams of each pollutant emitted per brake horsepower hour.

(d) When an engine is tested for exhaust emissions or is operated for durability testing on an engine dynamometer, the complete engine shall be used with all standard accessories which might reasonably be expected to influence emissions to the atmosphere installed and functioning.

§ 85.101 Fuel Specifications

(a) For exhaust emission testing of gasoline fueled engines, fuel having specifications as shown in the table in § 85.71(a), or substantially equivalent specifications approved by the Administrator shall be used.

(b) For durability testing of gasoline fueled engines, fuel having specifications as shown in the table in § 85.71(b), or substantially equivalent specifications approved by the Administrator, shall be used. The octane rating of the fuel used shall be in the range recommended by the engine manufacturer. The specifications of the fuel to be used shall be reported in accordance with § 85.51(b)(3).

(c) For exhaust emission testing of engines which use diesel fuels, fuel having specifications as shown in the table in § 85.121(b), or substantially equivalent specifications approved by the Administrator shall be used.

(d) For durability testing of engines which use diesel fuels, fuel having specifications as shown in the table in § 85.121(c), or substantially equivalent specifications approved by the Administrator, shall be used. The octane rating of the fuel used shall be in the range recommended by the engine manufacturer. The specifications of the fuel to be used shall be reported in accordance with § 85.51(b)(3).

§ 85.102 Dynamometer Operation Cycle

(a)(1) The following twenty three mode cycle shall be used in dynamometer operation tests of heavy duty engines.

MODE NO.	ENGINE SPEED*	PERCENT LOAD	WEIGHTING FACTOR
1	Idle	0	~~6.0~~ 7
2	Intermediate	2	6.0
3	"	8	6.0
4	"	18	5.0
5	"	25	3.0
6	"	50	6.0
7	"	75	0
8	"	82	4.0
9	"	92	0
10	"	100	0
11	Idle	0	~~6~~ 7
12	Intermediate	C.T.	12
13	High	100	2.5
14	"	92	5.5
15	"	82	3.5
16	"	75	6.0
17	"	50	6.0
18	"	25	0
19	"	18	6.5
20	"	8	0
21	"	2	0

MODE NO.	ENGINE SPEED*	PERCENT LOAD	WEIGHTING FACTOR
22	Idle	0	~~6~~ 8
23	High	C.T.	6

---

* Engine Speed Definition:

	Engine Type	
	Spark Ignition	Compression Ignition
Intermediate	1200 rpm	Peak torque speed or 60% of rated, whichever is higher.
High	2300 rpm	Rated speed

(2) For each mode the engine dynamometer shall be operated at a constant speed within ± 50 r.p.m. of the specified speed and at the specified torque within ± 2 percent of maximum torque at that speed. For example, the torque for mode six (6) shall be between 48 and 52 percent of maximum torque measured at the intermediate test speed.

(b) The following equipment shall be used for emission testing of engines on engine dynamometers.

(1) An engine dynamometer with adequate characteristics to perform the test cycle described in § 85.102(a)

(2) An engine cooling system having sufficient capacity

to maintain the engine at normal operating temperatures during conduct of the prescribed engine tests.

(3) A chassis-type exhaust system or substantially equivalent exhaust system.

§ 85.104 Sampling and Analytical Systems for Measuring Exhaust Emissions

(a) Two separate sampling and analytical systems are used for emission testing under the regulations in this part. One system is used for the determination of hydrocarbon concentrations. The other system is used for the determination of the concentrations of nitric oxide, carbon monoxide, and carbon dioxide.

The system used for determining hydrocarbon concentrations includes a heated sampling line and a heated flame ionization detector analyzer (FID). When emission tests involve gasoline fueled engines, the sample line and analyzer are maintained at a temperature of 160°F ± 5°F to prevent the water vapor in the sample stream from condensing out and collecting in the system. When emission tests involve engines which use diesel type fuels, the temperature is maintained at 350°F ± 10°F to inhibit the accumulation of the lighter weight hydrocarbons in the system as a result of condensation and adsorption effects. Means are provided for purging the system with air when measurements are not being made.

The system used for determining the concentrations of the other pollutants includes:

(1) a water concending trap which is maintained at 36°F ± 4°F,

(2) a chemiluminescence (CL) NO analyzer,

(3) a nondispersive infrared (NDIR) CO analyzer and,

(4) a nondispersive (NDIR) CO_2 analyzer.

A converter is used upstream of the chemiluminescence analyzer to convert any NO_2 in the sample stream to NO. A bypass system is provided to permit the periodic checking of the converter efficiency. Means are provided for back flushing the cooling coil and sample line and for introducing air or NO and O_2 mixtures (for converter efficiency testing) into the analytical system.

Other types of analyzers may be used if they yield equivalent results and if they are approved by the Administrator.

(b) Schematic drawing. The following (Fig. 6) is a schematic drawing of the exhaust gas sampling and analytical system which shall be used for testing under the regulations in this subpart.

(c) Component description. The following components will be used in the exhaust gas analytical system for testing under the regulations of this part.

(1) Flowmeters (FL1, FL2, and FL3) to indicate the sample flow rate through the analyzers.

(2) Analyzers to determine hydrocarbon, carbon monoxide, carbon dioxide, and nitric oxide concentrations.

(3) A converter to convert any NO_2 present in the samples to NO before analysis.

(4) Flow control valves (N1, N2, N3, N4, N5, N6, N7, N8, N9, N10, N11, N13, and N14) to regulate the gas flow rates.

(5) Recorders (R1, R2, R3, and R4) or digital printers to provide permanent records of calibration, spanning, and sample measurements. In those facilities where computerized data acquisition systems are incorporated, the computer facilities printout may be used.

(6) Manifold (M1) to collect the expelled gases from analyzers.

(7) Pump (P2) to transfer expelled gases from the collection manifold to a vent external to the test room (optional).

(8) Selector valve (V8) to direct purge air through the HC analytical system.

(9) Selector valves (V1, V2, V5, V6) to direct samples, span gases, or zeroing gas to the analyzers.

(10) Selector valves (V3 and V4) to allow the sample, span, calibrating, or zeroing gases to bypass the converter.

(11) Pump (P1) to transfer samples from sample probe to analyzers.

(12) Filters (F1 and F2) to remove particulate matter.

(13) Selector valve (V9) to direct NO/O_2 mixtures to the converter for efficiency checks.

(14) Selector valve (V7) to backflush cooling coil with air.

(15) Cooling Coil (C1) to condense water vapor from sample.

(16) Refrigerated water bath to maintain cooling coil at 32 - 40°F.

(17) Thermometer for indicating bath temperature.

(18) Valve (N12) to drain water from cooling coil.

(19) Sample probes to extract exhaust gas sample downstream of muffler.

§ 85.105 Information

The following information shall be recorded:

(a) General

- (1) Test number
- (2) Date and time of day
- (3) Instrument operator
- (4) Engine operator
- (5) Engine Identification - Date of manufacture - Number of hours of operation accumulated on engine - Engine family - engine displacement - timing - maximum observed torque at specified test engine speeds - idle r.p.m.
- (6) All pertinent instrumentation information such as model name and serial numbers.
- (7) Recorder charts. Identify zero traces - Calibration or span traces for each test mode - Start and finish of each test.
- (8) Ambient temperature in dynamometer testing room.
- (9) Engine intake, air temperature, and humidity.
- (10) Barometric pressure.
- (11) Observed engine torque for each mode.
- (12) Other data as required by the Administrator.

(b) Spark ignition engines

- (1) Number of carburetors and number of carburetor venturis or fuel injection system types.

(2) Advertised horsepower.

(3) Fuel consumption in gms/hr during each mode.

(c) Compression ignition engines

(1) Advertised rated and peak torque speeds.

(2) Exhaust pipe diameter.

(3) Exhaust system back pressure.

(4) Air aspiration system type.

(5) Air inlet restriction.

(6) Fuel injection system.

(7) Exhaust flow in c.f.m., or intake air flow in c.f.m. and fuel consumption in pounds per hour, for each mode.

§ 85.106 Calibration and Instrument Checks

(a) Calibrate the analytical assembly at least once every 30 days. Use the same flow rate as when analyzing samples.

(1) Adjust analyzers to optimize performance.

(2) Zero the hydrocarbon analyzer with zero grade air and the carbon monoxide, carbon dioxide, and oxides of nitrogen analyzers with zero grade nitrogen. The allowable zero gas impurity concentrations should not exceed 1 p.p.m. equivalent carbon response, 1 p.p.m. carbon monoxide, 300 p.p.m. (0.03 mole percent) carbon dioxide, and 0.1 p.p.m. nitric oxide.

(3) Set the CO and CO_2 analyzer gains to give the desired ranges. Select the desired attenuation scale of the HC analyzer and set the capillary flow rate by adjusting the back pressure regulator, to give the desired range. Select the desired scale of the NO_x analyzer and adjust the phototube high voltage supply to give the desired range.

(4) Calibrate the HC analyzer with propane (air diluent) gases having nominal concentrations equal to 50 and 100 percent of full scale. Calibrate the CO analyzer with carbon monoxide (nitrogen diluent) gases and the CO_2 analyzer with carbon dioxide (nitrogen diluent) gases having nominal concentrations equal to 10, 25, 40, 50, 60, 70, 85, and 100 percent of full scale. Calibrate the NO_x analyzer with nitric oxide

(nitrogen diluent) gases having nominal concentrations equal to 50 and 100 percent of full scale. The actual concentrations should be known to within ± 2 percent of the true values.

(5) Compare values obtained on the CO and CO_2 analyzers with previous calibration curves. Any significant change reflects some problem in the system. Locate and correct problem, and recalibrate. Use best judgment in selecting curves for data reduction.

(6) Check the NO_2 to NO converter efficiency by the following procedure:

(i) Fill a plastic bag with air (or oxygen) and NO span gas in proportions which result in a mix in the operating range of the analyzer. Provide enough oxygen for substantial conversion of NO to NO_2.

(ii) Knead bag and immediately connect the bag to the inlet at valve N13. Turn selector valve N7 as required and close valve V8. Alternately measure the NO and NO_x concentration at 1-minute intervals by alternately passing the sample throug the converter and the bypass (close valves N6 and N9 to minimize pump down rate of bag). After several minutes of operation, the recording of NO and NO_x will resemble Figure 1c, Section

85.84, if the converter is efficient. Even though the amount of NO_2 increases with time, the total NO_x ($NO + NO_2$) remains constant. A decay of NO_x with time indicates the converter is not essentially 100 percent efficient and the cause should be determined before the instrument is used.

(iii) The converter efficiency should be checked at least once weekly and preferably once daily

(b) HC, CO, CO_2, and NO_x measurements: Allow a minimum of 20 minutes warmup for the HC analyzer and 2 hours for the CO, CO_2, and NO_x analyzers. (Power is normally left on infrared and chemiluminescence analyzers; but when not in use, the chopper motors of the infrared analyzers are turned off and the phototube high voltage supply of the chemiluminescence analyzer is place in the standby position.) The following sequence of operations should be performed in conjunction with each series of measurements:

(1) Zero the analyzers. Obtain a stable zero on each amplifier meter and recorder. Recheck after tests.

(2) Introduce span gases and set the CO and CO_2 analyzer gains, the HC analyzer sample capillary flow rate, and the NO_x analyzer high voltage supply to match the calibration curves. In order to avoid corrections, span and calibrate at the same flow

rates used to analyze the test samples. Span gases should have concentrations equal to approximately 80 percent of full scale. If gain has shifted significantly on the CO or CO_2 analyzers, check tuning. If necessary, check calibration. Recheck after test. Show actual concentrations on chart.

(3) Check zeros; repeat the procedure in subparagraphs (1) and (2) of this paragraph if required.

(4) Check flow rates and pressures.

(5) Measure HC, CO, CO_2, and NO_x concentrations of samples. Care should be exercised to prevent moisture from condensing in the sample collection bag.

(6) Check zero and span points.

(c) For the purposes of this section, the term "zero grade air" includes artificial "air" consisting of a blend of nitrogen and oxygen with oxygen concentrations between 18 and 21 mole percent.

§ 85.107 Test Run

(a) The temperature of the air supplied to the engine shall be between 68°F and 86°F. The observed barometric pressure shall be between 28.5 inches and 31 inches Hq. Higher air temperature or lower barometric pressure may be used, if desired, but no allowance will be made for possible increased emissions because of such conditions.

(b) The following steps shall be taken for each test:

(1) Install instrumentation and sample probes as required.

(2) Start cooling system.

(3) Start the engine, warm it up and precondition it by running it at the lower specified test speed and maximum horsepower for 10 minutes or until all temperatures and pressures have reached equilibrium.

(4) Determine by experimentation the maximum torque at the specified test engine speeds and calculate the torque values for the specified test modes.

(5) Zero and span emission analyzers.

(6) Start the test sequence of § 85.102(a). Operate the engine for ten minutes in each mode as follows:

Minute	Mode Test Sequence
1st	Complete engine speed and load changes
2nd through 7th	Pass air through sample lines and analyzers
8th through 10th	Pass exhaust sample through the lines and analyzers and continuo record analyzer response.

(7) Read and record the data required for § 85.105 during the last five minutes of each test mode.

(8) Check and reset the zero and span settings of the emission analyzers at the end of the first CT mode (mode # 12) and at the end of the test or more often if required. If a change of over two percent of full scale response is observed, make necessary adjustments to the analyzers and repeat all test modes since the last zero and span.

(9) Backflush condensate trap and replace filters as required.

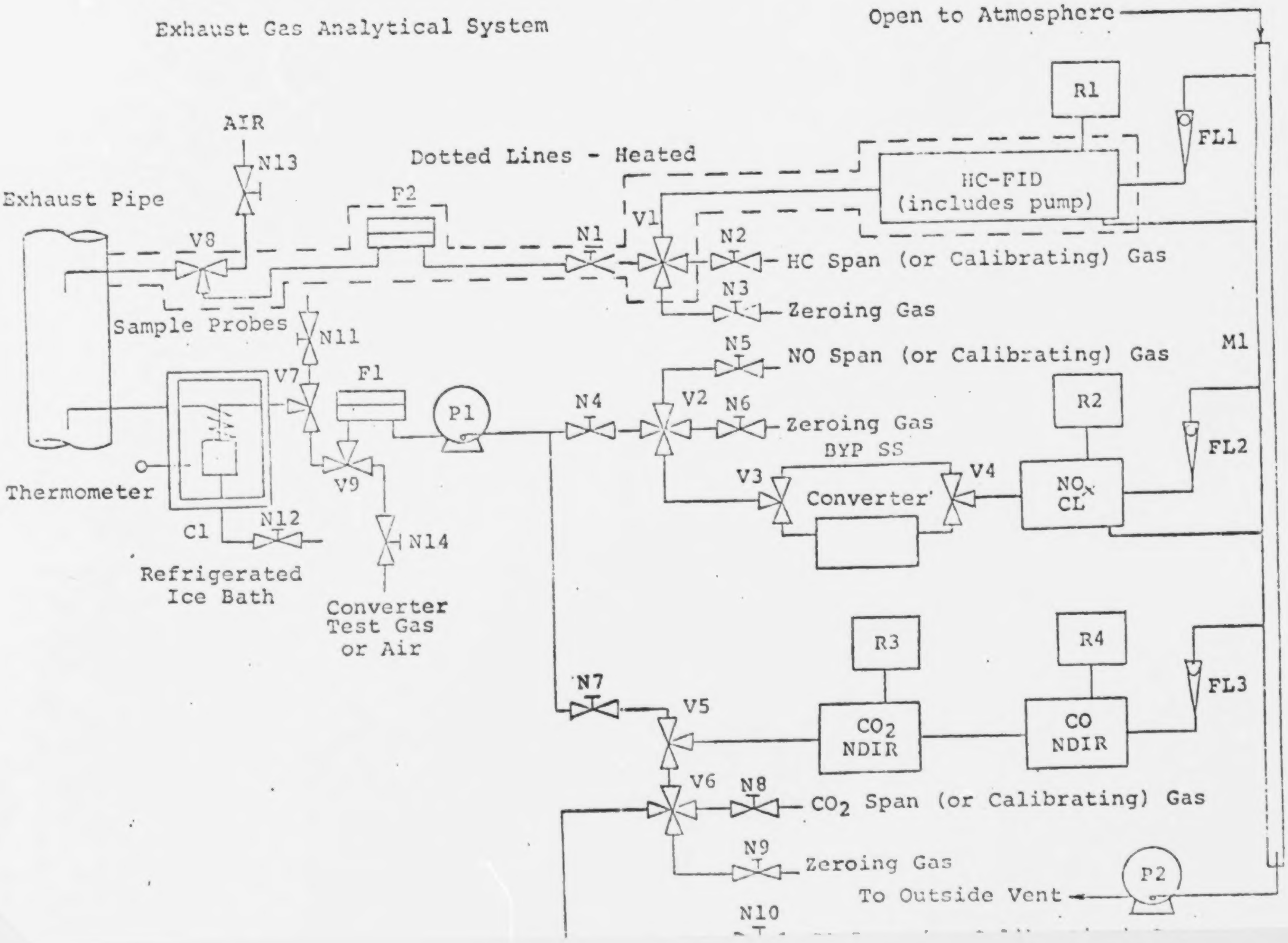
§ 85.108 Chart Reading

(a) Locate the last sixty seconds of each mode and determine the average chart reading for HC, CO, CO_2, and NO over the one minute period.

(b) Determine the concentration of HC, CO, CO_2, and NO during each mode from the average chart readings and corresponding calibration data.

Figure 6

Exhaust Gas Analytical System


Open to Atmosphere
R1
FL1
AIR
N13
Dotted Lines - Heated
Exhaust Pipe
F2
V8
N1
V1
N2
HC-FID (includes pump)
HC Span (or Calibrating) Gas
N3
Zeroing Gas
Sample Probes
N11
N5
NO Span (or Calibrating) Gas
M1
V7
F1
P1
N4
V2
N6
Zeroing Gas
R2
FL2
BYP SS
V3
Converter
V4
NOx CL
Thermometer
V9
C1
N12
N14
Refrigerated Ice Bath
Converter Test Gas or Air
R3
R4
FL3
N7
V5
CO2 NDIR
CO NDIR
V6
N8
CO2 Span (or Calibrating) Gas
N9
Zeroing Gas
P2
To Outside Vent
N10

Office of Air Programs
Ann Arbor, Michigan 48105

AFAE

March 27, 19

Corrections to the Experimental Heavy-Duty Test Procedure
Presently Utilized at Southwest Research Institute and the
Bureau of Mines

Dr. Jose L. Bascunana
Chief, Highway Vehicles Section, CCDB

In Section 85.102(a)(1) the weighting factors for mode numbers 1, 11, and 22 are revised to read as follows:

Mode No.	Engine Speed	% Load	Weighting Factors
1	Idle	0	7
11	Idle	0	7
22	Idle	0	8

In Section 85.107 paragraphs (6) and (7) are revised to read as follows:

(6) Start the test sequence of 85.102(a). Operate the engine for at least three minutes in each mode, completing the engine speed and load changes during the first minute.

(7) If additional time is required to read and record the data specified in Section 85,105, each mode may be extended to a maximum of ten minutes.

In Section 85.108 paragraph (a) is revised to read as follows:

(a) Locate the third minute of each mode and determine the average chart reading for HC, CO, CO_2 and NO over the one minute period.

John Bozek
Chief, Heavy Duty Section
Procedures Development Branch

AFAE::JJMcFadden/JBozek:lpm 209, 340, 3/27/72

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APPENDIX B

CHEMICAL - ANALYTICAL PROCEDURES

OXYGENATED COMPOUNDS IN AUTOMOBILE EXHAUST-GAS CHROMATOGRAPHIC PROCEDURE

Fred Stump

1. Principles and Applicability

1.1 This method is applicable for the characterization of oxygenated compounds in automobile exhaust.

Aldehydes have been shown (1) to be about as photochemically reactive as olefins. The aldehydes are believed to be contributors to eye irritation as well as odors that are common in polluted atmospheres.

Analysis of exhaust samples from catalytic and non-catalytic cars show that formaldehyde, acetaldehyde, acetone/acrolein/propionaldehyde, crotonaldehyde and benzaldehyde are consistently present in vehicle emissions withiso-butyraldehyde and hexanaldehyde being intermittently observed. With the present analytical equipment setup acetone, acrolein, and propionaldehyde have the same chromatographic relative retention time. Since the components in this time zone are not resolved, all effluents occuring at this retention time are calculated as acetone.

1.2 The vehicular exhaust is first diluted in a constant volume sampler system and then a portion of this dilute exhaust is pulled through a manifold sampling system. The sample is taken through two impingers in series each of which contains 40 ml of absorbing reagent. The absorbing reagent is a solution of 2,4-Dinitrophenylhydrazine in 2N HCl. The carbonyl compounds present in the sample stream react with the absorbing reagent forming soluble and insoluble derivatives which are removed by filtration and extraction techniques. These separated derivatives are then dried, and the soluble and precipitated portions are recombined prior to analysis. A single gas chromatographic analysis is then made to characterize the combined sample.

2. Range and Sensitivity

The mechanics of the method (sampling volumes, extraction techniques, and analytical procedure) were designed around the established dilution (CVS) system and then set-up manifold sampler. The analytical procedure has been shown to have a total recovery of better than 95% when the effluent concentrations are in the range of 0.01 to 30 parts per million.

The limits of detectability as well as the range can be easily adjusted to satisfy all measurement conditions that have been encountered up to the present time.

3. Interferences

No significant interferences in the method have been detected.

4. Precision, Accuracy and Stability

4.1 Precision

Data obtained from 5 repetitive injections of standard derivatives in benzene has shown the maximum deviation to be 0.8% for benzaldehyde and a minimum deviation of 0.3% for formaldehyde.

4.2 Accuracy

The data obtained from a standard mix of derivatives in absorbing reagent solution (to simulate actual sample recovery conditions) indicate a recovery in excess of 97%.

4.3 Stability

Data from standard mixes indicate that no significant concentration changes occurred when the solution was left standing for a period of 5 days.

5. Apparatus

5.1 Hardware

A. Perkin-Elmer 900 Gas Chromatograph with dual columns and flame ionization detectors with a single differential amplifier.

B. Perkin-Elmer PEP-1 Data Systems for peak area retention time and area integration.

C. Electronik 19 Model Honeywell recorder for chromatographic display.

D. Dual column 24 x 1/8 inch O.D. (0.093) stainless steel tubing packed with 6.7% Dexsil (polycarboranesiloxane) 300 GC on Chromosorb G 60/80 mesh, DMCS treated and acid washed.

E. 100 ml capacity impinger type scrubbers. Ace Glass # 7530-07.

F. 125 ml capacity vacuum and volatile liquid flasks.

G. Calibrated rotometers capable of measuring at least 3 liters per minute.

H. Three fritted glass filters porosity "D", ASTM 10-20 microns pore size. Ace Glass Company

I. Separatory funnels 125 and 250 ml capacity.

J. Separatory funnel shaker, Wrist-Action ® type with appropriate funnel holders.

K. Nitrogen manifold or explosion proof constant temperature vacuum oven.

L. Volumetric dispensing flasks, wash bottles, graduated cylinders, and 1 dram vials.

M. Ring stands, labels, holders, tubing, fittings and clamps needed for equipment manipulation.

N. Pump, Gast Model 0211-P103A-G8C.

O. Heated manifold, See Figure 2.

6. Reagents

6.1 Pentane, Spectroquality

6.2 2,4-Dinitrophenyhydrazine (2,4-DNPH).

6.2.1 A 2N HCl solution of reagent grade 2,4-DNPH, saturated at 0°C is prepared as follows:

A. To a 1-liter volumetric flask containing about 500 ml of distilled water, add 163 ml of concentrated HCl and 2.5 grams of the 2,4-DNPH crystals.

B. Dissolve crystals using either an ultrasonic generator bath or an automatic stirrer with a teflon coated stirring bar.

C. If reagent is not to be used immediately, store the stoppered flask in a refrigerator as near to 0°C as possible. The storage period should not exceed 10 days. Discard solution if crystals begin to form before this ten day period expires.

6.2.2 Due to contamination present in both the pentane and 2,4-DNPH reagents it is more expedient to obtain a background by performing at least duplicate extractions on the absorbing reagent in the same manner as samples are treated. Since the contaminants vary in concentration from lot to lot it will be necessary to obtain a background when new lots or batches of reagents are introduced. These background values have been found to be extremely vital in correcting sample concentrations.

6.3 Sodium Bicarbonate

7. Procedure

7.1 Calibration

7.1.1 Anthracene functions as the internal standard and is presently prepared at a concentration of 0.041580 mg/ml. The anthracene is dissolved in spectroquality Benzene and two ml of this prepared solution is used to dissolve the dried oxygenate derivatives prior to analysis.

7.1.2 Response factors for the individual carbonyls are determined from standard concentrations of pure 2,4-DNPH derivatives in spectroquality Benzene. The purity of the synthesized derivatives must be checked by a melting point (2) determination before derivatives are used to obtain the response factors. Typical response factors and concentration repeatability for the hydrazone derivatives normally found in exhaust are shown in Table I. The response factors for each carbonyl is calculated from the following equation:

$$\text{Response Factor (F)} = \frac{\text{Anthracene Area}}{\text{Derivative Area}} \times \frac{\text{mg/ml Derivative}}{\text{mg/ml Anthracene}}$$

7.2 Oxygenate collection and recovery

7.2.1 Sample Collection

A. Pipette 40 ml of reagent solution into 6 impingers.

B. The two impingers are connected in series for each bag so that the collection efficiency can be calculated.

C. Place the assembled impingers in an ice bath.

D. Collect the samples noting the flow rate, room temperature, barometric pressure and total sampling time.

E. The sample is taken through a heated manifold system connected into the dilution system and collected under the conditions described in the Federal Register, Volume 37, Number 221, Part II, Wednesday, November 15, 1972, New Motor Vehicles and New Motor Vehicles Engines.

F. The manifold collection system is electrically slaved to the CVS dilution system so that the impinger sampling time corresponds to Federal Cycle run times.

G. Disconnect the impingers from the manifold. Partially remove the impinger tube assembly until the stem is above the liquid and wash any precipitates and reagent from both the internal and external surfaces of the stem with a few milliters of distilled water. Allow the excess water to drain from the stem and remove the impinger tube from the absorber bottle. Let sample set at room temperature at least one hour before proceeding to the filtration and extraction steps.

7.2.2 Samples containing precipitates

A. Attach the side arm of a 125 ml vacuum flask containing a fritted glass filter to a vacuum line and apply vacuum.

B. Transfer the contents of the absorber to the fritted glass filter assembly and rinse absorber with small portions of distilled water.

C. Wash the precipitate on the fritted filter with a few ml of distilled water.

D. Shut off vacuum and transfer contents of vacuum flask to a 125 ml separatory funnel. Rinse vacuum flask with small volumes of distilled water until rinse is essentially colorless.

E. Remove filter with precipitates and put a second filter on the flask and apply vacuum. Repeat steps B through D for each succeeding sample.

F. Dry filters under a steam of nitrogen or in a vacuum oven at 50°C and 18" water vacuum. Set the filters with the dried precipitate until the filtrate has been processed then proceed to step G.

G. When precipitate is dry place the filter on a dry 125 ml vacuum flask.

H. Pour 15 ml of methylene chloride over the precipitate and let set for approximately 30 seconds until the precipitate has dissolved. Apply vacuum and pull the solution through the filter. Add a second 15 ml of methylene chloride to the filter and gently swirl around to wash the filter funnel as well as to dissolve any residual materials. Apply vacuum to pull this second volume of methylene chloride into the vacuum flask.

I. Transfer the dissolved hydrazines with a 15 ml washing of methylene chloride to the 125 ml gas tight flask, containing the dried extract corresponding to this precipitate.

J. Repeat steps A through I for each sample containing a precipitate.

7.2.3 Samples With No or Removed Precipitates

A. Transfer contents of absorber or vacuum flask to a 125 ml separatory funnel washing the absorber bottle or flask with small volumes of distilled water.

B. To the separatory funnel containing the absorbing reagent, add 40 ml of pentane (the background of which has been determined). Stopper the funnel and then put it into the automatic shaker holder. Vent the funnel. Start the shaker and let it shake for 5 minutes.

C. Stop shaker and vent funnel. Allow the two-phase system to separate, collecting the lower phase in a second separatory funnel. Transfer the remaining pentane extract portion to a 250 ml separatory funnel. Add a second 40 ml of pentane to the already once extracted sample solution. Repeat steps B and C.

D. Repeat steps B and C a third time.

E. To the 250 ml separatory funnel containing the 120 ml of pentane extract drain off the absorbing reagent which had been transferred with the pentane.

F. Add 25 ml of distilled water to the funnel, then approximately 1/4 to 1/2 grams of sodium bicarbonate. Wash lip of funnel free of material, put stopper in funnel and then manually shake for 30 seconds.

G. Let phases separate and drain the wash water from the funnel, and again add 25 ml of distilled water and repeat the shaking. After the phases have separated, drain off the water, insuring that all traces are removed, as the presence of water will now extend the time required to evaporate the extract to dryness.

H. Wipe lip of funnel with a dry paper towel and transfer the contents to a clean, dry 125 ml air tight flask. The flasks can either be placed in a vacuum oven at 50°C and 18 inches of water vacuum or under a steam of dry nitrogen until the pentane has been removed and only the dried derivatives remain.

I. Repeat steps A through H for each sample.

J. When the samples have come to dryness, remove from oven or nitrogen steam and set aside until the precipitates have been processed.

K. After the precipitates have been dried and dissolved in methylene chloride add this solution to the flasks containing the dried extracted portion of the sample. This solution is then taken to dryness under the conditions in step H above.

L. Pipette into each of the 125 ml gas tight flasks containing the dried 2, 4-DNPH derivatives (extract and precipitate) 2 ml of the Internal Standard (Anthracene in Benzene) Solution and place the flask in a sonic bath until the residue has dissolved. Visually examine the bottom of the flasks, by holding up to a light area, to insure that all of the residue has completely dissolved.

M. Transfer the solution from step L to a labeled 1 dram vial in preparation for gas chromatographic injection.

7.3 Analysis

7.3.1 Optimization of Parameters

A. Prior to calibration and determination of response factors the hydrogen, helium (carrier), and air flows must be optimized using a standard mix in benzene. This flow-response calibration procedure can be found in most gas chromatographic books.

B. The conditions presently in use were obtained by first optimizing the hydrogen-air flows at low, medium, and high helium carrier rotometer settings. A number of injections were made at each of the above conditions using different sample sizes. The best chromatographic conditions, flow rates measured at detector, were found to be at a helium flow rate of 40.0 cc/min., hydrogen flow rate 45.5 cc/min., and air at a flow of 600 cc/min. with a sample size of 15 microliters.

7.3.2 Technique

A. Condition the chromatograph column with a 15 microliter portion of either a standard mixture or sample prior to obtaining concentration data. A conditioning process should be repeated whenever samples are not analyzed for an hour or more.

B. The injection is on-column using a 25 microliter syringe. Before injection, at least 3-25 microliter portions of the sample is used to condition the syringe. A 25 microliter portion is then taken into the syringe and syringe laid on a clean paper towel. The chromatograph lid is raised and a wrench is used to remove the column tee cap. The tee is a 3-way fitting shaped the capital "T" and is situated such that the vertical section of the "T" is on the horizontal plane. A cap is placed on one side of the "T" top and the column of the other side. The carrier gas enters the side arm and exits through the column side of the "T". The syringe is then taken up and the volume adjusted from 25 to 15 microliters. The syringe tip is wiped free of any liquid and then inserted through the "T" into the column and the plunger firmly pushed in. The syringe is removed and a cold cap put on the tee, tightened, and then the lid closed. When the chromatograph responds to the benzene solvent the GC programmed start button is pressed simultaneously with the inject data systems interface initiator. The syringe is then washed several times with clean benzene in preparation for the next injection.

C. The GC temperature is programmed from 130°C to 300°C at a rate of 6°C per minute. Injection block temperature is 240°C and the manifold temperature held at 300°C.

D. See Figure I for a typical exhaust chromatogram of a non-catalytic automobile.

8. Calibrations

8.1 Absorber Inefficiency-Series Impingers

8.1.1 Using a Programmable Calculator

Corrections for absorber inefficiency for an infinite number of absorbers is based on the material balance concept. This method for determining the total concentration of carbonyl compounds using two absorbers in series has been verified within experimental error using a multiple impinger train.

These calculations are essential for an accurate determination of, particularly, the acetaldehyde and acetone concentrations. The percent of acetaldehyde passing through the first absorber is about 7.5% of the material present in the absorber and for acetone/acrolein/propionaldehyde is in the order of 20% of the material in the first absorber.

Calculations for series impingers are made by using the following equations:

First using the formula

$$R_n = A_0 + A_1 \sum R_i$$

when R_n = Concentration in each absorber

$$\sum^{N-1} R_i = \text{sum of individual absorber concentrations}$$

The concentrations present in the series absorbers are used to determine the constants A_0 and A_1.

The constants A_0 and A_1 are then used to calculate the total uncorrected concentration by equation.

$$C_0 = \frac{A_0}{K} = \frac{A_0}{A_1 V_s}$$ where:

A_0 = material removed from sample stream by first absorbers.

A_1 = material removed by second and succeeding absorbers.

V_s = sample volume

K = Constant

The value of C_0 is then corrected by a background subtraction.

For example:

Since the material balance concept dictates that the quantity of material absorbed by each of the absorbers in a train is related, then the linear regression equation can be used to determine the values of the slope and intercept of any two absorbers in series. Know these two constants for any two absorbers the total concentration can then be calculated for the sample steam.

Example:

Absorber in train	Concentration in Absorber
1st	.1600
2nd	.0800
3rd	.0400
4th	.0200

Data Points:

R_n (y)	$\sum^{N-1} R_i$ (x)
.1600	0
.0800	.1600
.0400	.2400
.0200	.2800

When calculated for an infinite number of absorbers.

$$C_0 = \frac{A_0}{A_1} = \frac{.16}{.50} = .32$$

8.1.2 Alternate Method

An alternate method for doing the calculations if a programmable calculator is not available would be run two absorbers in series and then based on this information a per cent of the material passing through the first impinger could be determined. This per cent could then be applied to any number of hypothetical absorbers and then summed to give a total concentration.

After sufficient data has been obtained on series absorbers then only one absorber can be run and calculations made, with confidence, to get a total concentration.

8.2 Carbonyl Concentration

$$\text{Carbonyl (ppm)} = C_1 \times \frac{1}{V_s} \times \frac{T_r}{P_r} \times \frac{F}{MW} \times \frac{2\ \text{I.S.} \times 10^3}{\frac{T_o}{P_o V_o}}$$

C_1 = Co corrected for background
V_s = Sample volume in liter
T_r = Room temperature, °K
P_r = Room pressure, mm Mercury
F = Response factor for individual carbonyl
MW = Molecular weight of carbonyl derivative
I.S. = Internal Standard Concentration, mg/ml
T_o = Temperature at Standard Conditions
P_o = Pressure at Standard Conditions
V_o = Volume at Standard Conditions

TABLE 1. STANDARD MIXTURE OF 2,4-DNPH DERIVATIVES FOR THE CALIBRATION OF THE CHROMATOGRAPHIC SYSTEM

			Ratio Anthracene to 2,4-DNPH		
2,4-DNPH Derivative	Number of Determinations	Concentration mg/ml	$\bar{X}$	Standard Deviation	F-Factor
Formaldehyde	5	0.09896	1.0851	0.0032	2.5293
Acetaldehyde	5	0.10395	0.9181	0.0028	2.2481
Acetone	5	0.08040	1.0498	0.0049	1.9926
Iso-Butyraldehyde	5	0.02840	2.9385	0.0127	1.9653
Crotonaldehyde	5	0.04487	2.0720	0.0096	2.1902
Hexanaldehyde	5	0.01497	5.3590	0.0144	1.8898
Benzaldehyde	5	0.06550	1.3593	0.0104	2.0972

Procedure Used by SFRE for BaP Analysis

The analytical procedure used for this work followed that described by Sawicki et at. (Health Lab. Sci. 7 (1) Suppl., Jan., 1970) with some minor modifications. In general, the procedure is as follows:

1. Prewash Soxhlet equipment by refluxing benzene for 1 hour
2. Extract filter by Soxhlet method with benzene (distilled in glass) for 4 hours. (8" x 10" filter divided into measured sections of 4" x 5" to facilitate extraction process. Each filter portion was placed in a separate Soxhlet apparatus and the extracts combined after completion of the process).
3. Evaporate the solvent to a few ml volume and quantitatively transfer to a preweighed vial (this step allows separation of filter fiber residue from the sample). Evaporate the solvent and reweigh the vial to determine the weight of extractable material.
4. Add exactly 1 ml of solvent to the vial and redissolve the residue.
5. Spot 10 μl of this solution on a thin layer plate (alumina or silica gel) and develop with 19:1 hexane ether.
6. Scrape the plate in the region where the BαP separates using a high concentration marker as a guide.
7. Dissolve the adsorbed material and quantitatively filter to remove the insoluble particles.
8. Evaporate the filtrate to dryness and add 1 ml H_2SO_4
9. Read the fluorescence intensity with excitation at 470 nm and emission at 540 nm.
10. Known quantities of BαP spotted on TLC and extracted were used as comparison standards.

NEW BENZ α PYRENE ANALYTICAL METHOD

(Copy of report reference 63)

I. Equipment and Apparatus

- A. Fluorescence Spectrophotometer (Perkin-Elmer Model MFP-3) with the Thin Layer Plate Scanning Attachment
- B. Digital Integrator (Perkin-Elmer Model 048)
- C. Recorder (Hitachi Model QPD-33)
- D. Kudna Danish Concentrator, 10 ml concentrator tube with 250 ml flask
- E. Thin Layer Chromatography (TLC) Plates, Analtech 8" x 8" (250 μ) 20% acetylated cellulose.
- F. Plate Scoring Apparatus, Schoffel
- G. AIS TLC plate multispotter with 100 μl teflon coated blunt syringes
- H. Soxhlet Extraction Apparatus, Ꞩ 35 x 45.
- I. Soxhlet Extraction Thimbles, Whatman Cellulose (33 x 94)
- J. Filter, Kodak Yellow Chrome II
- K. Hot Plate

II. Chemicals

- A. Cyclohexane, triple glass distilled, source: Burdick & Jackson
- B. Benzene, Spectroquality, source: Fisher Scientific
- C. Benzene, ACS grade, source: Fisher Scientific
- D. Ethanol, Spectroquality, source: Fisher Scientific
- E. Methylene Chloride, Spectroquality, source: Fisher Scientific
- F. Benzo-α-Pyrene - Recrystalized three times, source: Dr. Eugene Sawiki in EPA, ESRL/RTP.

III. Calibration

Calibration standards of Benzo-α-Pyrene are prepared in the following concentration sets.

50 ng BaP/50 μl cyclohexane
25 ng BaP/50 μl cyclohexane
20 ng BaP/50 μl cyclohexane
15 ng BaP/50 μl cyclohexane
10 ng BaP/50 μl cyclohexane
5 ng BaP/50 μl cyclohexane
1 ng BaP/50 μl cyclohexane

Prepare a large enough batch to make several sets and freeze. Use either one fresh set or one thawed set daily. After one day's use, discard.

IV. Procedure

Note: For routinizing purposes we perform the analysis over a three-day period.

A. Day No. 1

A-1. Quarterly Composites of 1" x 8" glass fiber filter strips from an NASN site are received by the laboratory. [Five (5) to eight (8) strips constitute a valid quarterly composite.]

A-2. Samples are coded and logged into a laboratory notebook with all pertinent information, i.e., air volumes, site ID, year and quarter, number of strips, date received, etc.

A-3. Filter strips are rolled into units containing no more than three strips per unit. Up to three units may be stacked in one soxhlet extraction thimble.

Note: The thimbles are prewashed prior to use by refluxing for one hour in spectroquality benzene.

A-4. The composite strips are refluxed for six hours in 100 milliliters of cyclohexane.

A-5. Allow the soxhlet to cool, remove the extract and keep it in the dark or under yellow light until used during the second day.

B. Day No. 2

B-1. Place extracts in Kudna Danish Concentrators which are in a water bath maintained at 50°C. Blow extract down to 7 ml under a stream of dry nitrogen filtered through a molecular sieve (5A) trap.

B-2. Wash the sides of the concentrators with 10 ml fresh cyclohexane. Reconcentrate to 7 ml. The volumes are carefully brought to 10 ml with cyclohexane and the samples are transferred to 15 ml Teflon capped glass vials and stored in the dark and under 34°F refrigeration until used during the third day.

C. Day No. 3

C-1. Samples and calibration standards are removed from the refrigerator and freezer and allowed to warm to room temperature.

C-2. Using an AIS multispotter 50 µl of the samples, standards, blanks and spiked blanks are spotted on a TLC plate in 18 one cm channels scored by a Schoffel plate scoring device. Spotting time is approximately thirty (30) minutes.

Syringes (100 µl) with teflon blunt tips are loaded to the 90 µl mark and the plunger moved to the 80 µl mark. The 50 µl sample is measured from 80 µl to the 30 µl mark and the plate is removed from the spotter.

C-3. Plates are developed in TLC tanks to the 19 cm line in a solvent mixture of 100 ml ethanol and 50 ml methylene chloride. The plates are removed and allowed to air dry prior to scanning.

C-4. The plates are scanned using a Perkin-Elmer MPF-3 fluorescence spectrophotometer for benzo-α-pyrene using an excitation wavelength of 388 nm and read at an emission wavelength of 430 nm. The plates are then scanned at 434 nm ex and 470 nm em for anthanthrene.

C-5. The results are presented in both strip chart recordings and digital integrator readings.

Note: Recovery studies based on spiked blanks show an average recovery of 98.9 ± 5%.

All work is carried out under Kodak yellow chrome light.

Limit of detection based on the standard of a peak being 2 x the background noise is 0.1 ng.

V. Calculation

Where:

S = concentration of standard in nanograms
C = sample integrator counds
Cs = standard integrator counts
200 = spotting fraction, 50 µl spot from a 10 ml sample or 1/200

n = number of strips used per 10 ml sample
7 = total active area, in^2, of one strip
63 = total active area, in^2, of a whole filter
F = air flow through filter, M^3

$$\frac{(S)(C)(200)}{Cs} = \text{nanograms BaP/n}$$

$$\frac{(S)(C)(0.2)}{Cs} = \text{micrograns BaP/n}$$

$$\frac{(S)(C)(0.2)(63)}{(Cs)(n)(7)} = \text{micrograms BaP/filter}$$

$$\frac{(S)(C)(1.8)}{(Cs)(n)} = \text{micrograms BaP/filter}$$

$$1000 \times \frac{\mu\text{g BaP/filter}}{F} = \text{nanograms BaP/M}^3$$

Determination of Soluble Sulfates: Automated Method

1. Principle and Applicability

1.1 This method is for the determination of water-soluble sulfates from diluted automobile exhausts collected on Fluoropore filters. The method is quite general and may be used for trace sulfate analysis of any sample from which sulfates can be leached out with water or aqueous alcoholic solutions. There are interferences from some anions and methods for minimizing or eliminating these are still being worked out. The method as written is applicable to sulfate analysis of exhaust emissions from cars run on non-leaded gasoline.

1.2 Auto exhaust is mixed with air in a dilution tunnel and sampled through isokinetic probes. SO_3 reacts with available moisture in the exhaust to form H_2SO_4 aerosols and is trapped on Fluoropore* filters with 0.45 μ pore size. The filter is extracted with 60/40 isopropyl alcohol/water solution (i.e. 60 ml isopropyl alcohol (IPA) + 40 ml water). The extract is fed by a high pressure liquid (chromatographic) pump through a column of cation exchange resin to remove cationic interferences and then through a column of solid barium chloranilate where $BaSO_4$ precipitates out. An equivalent amount of reddish colored acid chloranilate ion is released[1,2] and is measured colorimetrically at 310 mμ[3,4]. To use this method for aqueous sulfate solutions, four parts by volume of the solution are mixed with six parts of IPA before feeding through the columns. Manual method or a dynamic sampling system can be used.

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*Registered trade mark. Obtainable from Millipore Corp.

2. Range and Sensitivity

Working concentration range and sensitivity depend on sample size. A sensitivity better than 0.5 µg $SO_4^{=}$ per ml in 60% IPA and working range of 0 - 25 µg/ml were obtained using a 0.5 ml external sampling loop injection system in conjunction with a du Pont liquid chromatograph UV detector. Sensitivity may be further increased by increasing the alcohol content of the solvent, as this would further decrease the solubility of $BaSO_4$ and barium chloranilate. This, however, requires a much tighter control of the water/IPA ratio in the sample and in the mobile phase. To minimize spurious results arising from water imbalance, it is recommended that both the extracting solvent and the mobile phase for analytical runs be taken from the same stock solution. Sample size as large as 1.5 ml has been successfully used.

3. Interferences

Cations interfere negatively by reacting with the acid chloranilate to form insoluble salts. These, however, are conveniently removed by passing the sample through a cation exchange resin in the acid form. Some anions such as Cl^-, Br^-, F^-, $PO_4^{\equiv}$ interfere positively by precipitating out as barium salts with subsequent release of acid chloranilate ions. Some buffer systems [2-5] are reported to minimize anion interference. These systems are being investigated for possible incorporation in the present procedure. Alternative clean-up methods are also under consideration. Fortunately, for non-leaded exhaust samples collected on filters, ionic interference is minimal. Interference from aromatic compounds is minimized by using a 300 mµ cut-off filter in the optical path of the detector system.

4. Precision, Accuracy, and Stability

4.1 Precision

With an external sampling loop of about 1.5 ml, photometer attenuation set to read .04 absorbance units full scale, standard deviation of 0.05 µg $SO_4^=$/ml was obtained for a sample containing 4.0 µg $SO_4^=$/ml.

4.2 Stability

4.2.1 Sulfuric acid standards containing 10 and 100 µg $SO_4^=$/ml in 60% IPA are stable for at least one month when stored in tightly capped volumetric flask which has been cleaned with 1:1 nitric acid and copiously rinsed with deionized water. Alternative storage containers are capped polyethylene reagent bottles.

4.2.2 The cation exchange resin and the barium chloranilate columns as described in apparatus section last for over two months. For samples known to contain cations, it is advisable to remove these cations by external treatment with cation exchange resin prior to injection into the sampling loop.

4.2.3 As the barium chloranilate column is depleted each time sulfate samples are fed through, it is good practice to run sulfuric acid standards before and after the sample.

4.2.4 Exposure of alcoholic samples, standards, and solvents to the atmosphere should be minimized, since IPA solution picks up atmospheric water on standing.

5. Apparatus

A schematic of the principal components of the automated set-up is shown in Figure 1.

5.1 Hardware

a. Reservoir (LR) for the solvent (60% IPA).

b. High pressure liquid pump (LP) capable of delivering liquids at flow rates of up to 3 ml/min at pressures as high as 1000 psi. Most liquid pumps used in high pressure liquid chromatography would be satisfactory.

c. Flow or pressure controller (FC).

d. Six-port high pressure switching valve (SV) equipped with interchangeable external loop (L).

e. Ultraviolet detector (D) equipped with appropriate filters to isolate a narrow band of radiation centered at 310 mμ. A microscope cover glass was found to be satisfactory.

f. Recorder to monitor detector response.

g. Automatic sampler (AS), such as the one used for a Technicon AutoAnalyzer.

h. Peristaltic pump (PP) to draw sample into sampling loop.

i. Cation exchange resin column (CX) - standard 1/4" O. D. x 10" stainless steel column packed with analytical grade Dowex 50W-X2 cation exchange resin in hydrogen form.

j. Barium chloranilate column (BC) - standard 1/4" O. D. x 5" stainless steel column packed with barium chloranilate.

5.2 Principle of Operation

Solvent (60% IPA) in reservoir (LR) is continuously fed through cation exchange (CX) and barium chloranilate columns at flow rates of about 3 ml/min. by a high pressure liquid pump (LP). Background absorbance is continuously measured by a UV detector (D) at 310 mμ and visually monitored in a strip chart recorder. A solenoid actuated air operated switching valve (SV) is used for filling the external sampling loop (L) with samples in conjunction with an automatic sampler (AS) and peristaltic pump (PP) and injecting the sample into the columns. At CX cations are removed and at BC, color reaction takes place. The $BaSO_4$ precipitate is retained in the column while the acid chloranilate is carried by the solvent through the detector system for colorimetric measurement.

For an automated sampling system such as shown in Figure 1, both SV and PP are electrically coupled to AS by electric relays such that both are activated whenever AS is sampling (i.e. L is being filled and mobile phase bypasses L). At the end of the sampling cycle, PP and AS stop and SV switches to the injection mode (i.e. mobile phase passes through L and carries sample through CX and BC columns).

For manual operation SV may be retained or replaced by a similar switching valve equipped with an extended handle for manual switching. Samples may be introduced into the sampling loop by syringe injection or by peristaltic pump system similar to the one used in the automated system.

6. Reagents

   6.1 Isopropyl alcohol (IPA) spectroquality grade or equivalent. Volatile solvent, safety class 1B.

   6.2 60% IPA. Add four parts water to six parts IPA by volume. Store in tightly capped bottle. About three liters are needed for a 12 hour operation.

   6.3 Barium chloranilate, suitable for sulfate analysis.

   6.4 Dowex 50W-X2 cation exchange resin, hydrogen form, 100-200 mesh.

   6.5 Hydrochloric acid (4N). Add 30 ml concentrated hydrochloric acid to 60 ml deionized water. (Danger, strong acid.)

   6.6 Standard sulfuric acid (1N). Dilute to the mark 2.8 ml of concentrated sulfuric acid with deionized distilled water in a liter volumetric flask which has been washed in 1:1 nitric acid and copiously rinsed with deionized distilled water. Standardized against accurately weighed sodium carbonate to get exact normality. 0.1N H_2SO_4 is equivalent to 4800 µg/$SO_4^=$/ml. (Danger, strong acid.)

   6.7 Standard sulfate solution (1000 µg $SO_4^=$/ml). Dissolve 1.4787 gm sodium sulfate which has been heated up to 105°C for four hours and cooled in a dessicator and dilute to 1000 ml.

7. Procedure

   7.1 Column preparation

      7.1.1 Barium chloranilate column (BC). In order to prepare a full column with minimum dead volume connect two lengths of standard 1/4" O. D. stainless steel tubings as shown in Figure 2. b = 2", a = 5". Connect a small funnel to open end of B with a Tygon tubing sleeve.

Fill the funnel half way with barium chloranilate and use a vibrator (i.e. electric pencil engraver) to pack the solid in column. Continue operation until B is about half filled. Remove funnel, plug empty space with glass wool, and cap the end with a 1/4" to 1/16" reducer. Plumb column B directly to SV in Figure 1. Connect a Tygon tubing at A and direct tubing to waste reservoir. Activate liquid pump, set flow controller at pressure drop of about 600 psi. Let solvent flow for 20 minutes. Deactivate pump, disconnect column from SV. Disconnect column A from column B. Connect a glass wool plugged 1/4" to 1/16" reducer to uncapped end of column A.

7.1.2 Cation exchange resin column (CX). Add cation exchange resin, 100-200 mesh, Dowex 50W-X2 to 80 ml of 4N HCl in a 150 ml beaker until a wet volume equivalent to 20 ml has settled at the bottom. Let soak for at least three hours with occasional stirring using a glass rod. Decant the acid, add 100 ml deionized distilled water, stir and slowly decant the liquid as soon as most of the solid has settled down at the bottom. Repeat rinsing procedure several times until rinse liquid gives a neutral reaction to pH paper.

Connect two standard 1/4" O. D. stainless steel tubings as in 7.1.1 with b = 5" and a = 10". Connect a small funnel to open end of B with Teflon or Tygon tubing sleeve. Clamp composite tube vertically and connect open end of A to vacuum line equipped with liquid trap. Fill funnel with deionized distilled water and turn on vacuum slowly until composite tube is completely filled with water. Add water until funnel is half-filled, stop vacuum and add slurry of freshly washed resin. Let resin settle by gravity until resin top is seen above B. Turn on vacuum slowly, keep adding resin slurry until composite tube is completely filled. Proceed as in 7.1.1 beginning with sentence: "Remove funnel, plug empty space..."

7.2 Priming System for Analytical Run

Connect the cation exchange and barium chloranilate columns with 1/4" union packed with glass wool as shown in Figure 1. Fill solvent reservoir (LR) with 60% IPA, activate liquid pump, detector, recorder, switching valve, sampler, and peristaltic pump. Allow to cycle normally to clean out all components. For this initial operation, dip the sampling probe in at least 100 ml of 60% IPA. Set liquid flow rate at about 3 ml/min. Let run for at least 30 minutes. Deactivate switching valve, sampler, and peristaltic pump. Leave other components in operating mode. When background is stable at attenuation of .01 absorbance units full scale, system is ready for analysis.

7.3 Preparation of Calibration Standards

Either sulfuric acid or sodium sulfate standards may be used.

Add 200 ml of 0.1 N H_2SO_4 aqueous stock solution to 300 ml 100% IPA in 500 ml volumetric flask. (Note: There is a volume decrease of about 2.7% when these proportions of water and IPA are mixed.) Dilute to the mark with 60% IPA. This is equivalent to 1,920 μg $SO_4^=$/ml in 60% IPA. Prepare from this alcoholic stock solution calibration standards in the range 0.5 - 25 μg $SO_4^=$/ml by dilution of appropriate aliquots with 60% IPA.

7.4 Extraction of Soluble Sulfates from Fluoropore Filters

Place filter in one oz. polyethylene bottle, add 10 ml 60% IPA and cap tightly. Shake until filter collapses and is completely immersed in liquid. Let stand overnight.

7.5 Analysis

Set instrument in operating mode, remove sampling probe from holder, and dip in 100 ml 60% IPA. Let it run at flow rate of 3 ml/min until stable background is obtained, then remount sampling probe to holder. In the meantime, fill sample cuvettes with sample extract and blank solutions (60% IPA) and place on turntable. Sampling pattern is blank, blank, sample, blank, blank at the rate of about six minutes per sample or blank. Blanks are used to wash out system between samples and minimize sample overlap. One blank between samples is adequate for dilute samples. (See also 5.2.)

A series of standards (see 7.3) is run, preferably before sample runs and calibration curve, peak height vs. concentration, is plotted. A control standard may also be placed after every ten samples as a quality check on the stability of the system.

The plot of peak height (detector response) vs. concentration (μg $SO_4^=$/ml) is non-linear in the low concentration end as would be expected from solubilities and kinetics consideration. Non-linearity is also observed at the upper end of the curve.

8. Calculations

Calculate the concentration of sulfate as µg $SO_4^=$/ml using the calibration curve. Total soluble sulfates $[SO_4^=]_F$ in filter is then given by:

$[SO_4^=]_F$ = (µg $SO_4^=$/m) x Vo x d

where: Vo = total volume of original sample extract

d = dilution factor

Example: Suppose 10 ml 60% IPA was used to extract the soluble sulfates in the filter and that 2 ml of this was diluted further to 6 ml with 60% IPA to bring detector response within calibration range. Suppose that the concentration of the diluted sample was found to be 5 µg/ml. Then,

$$[SO_4^=]_F = (5\ \mu g/ml) \times 10\ ml \times \frac{6}{2} = 150\ \mu g.$$

References

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2. Ibid, "Ultraviolet Spectrophotometric Determination of Sulfate, Chloride and Fluoride with Chloranilic Acid," Anal. Chem. 30, 202 (1958).

3. H. N. S. Schafer, "An Improved Spectrophotometric Method for the Determination of Sulfate with Barium Chloranilate as Applied to Coal Ash and Related Materials," Anal. Chem. 39, 1719 (1967).

4. S. C. Barton and H. G. McAdie, "An Automated Instrument for Monitoring Ambient H_2SO_4 Aerosol" in Proceedings of the Third International Clean Air Congress, Dusseldorf, Federal Republic of Germany, 1973, VDl-Verlag GmbH, 1973, p. C25.

5. M. E. Gales, Jr., W. H. Kaylor and J. E. Longbottom, "Determination of Sulphate by Automatic Colorimetric Analysis," Analyst 93, 97 (1968).

FIGURE 1

FLOW SCHEMATIC FOR AUTOMATED SULFATE INSTRUMENT

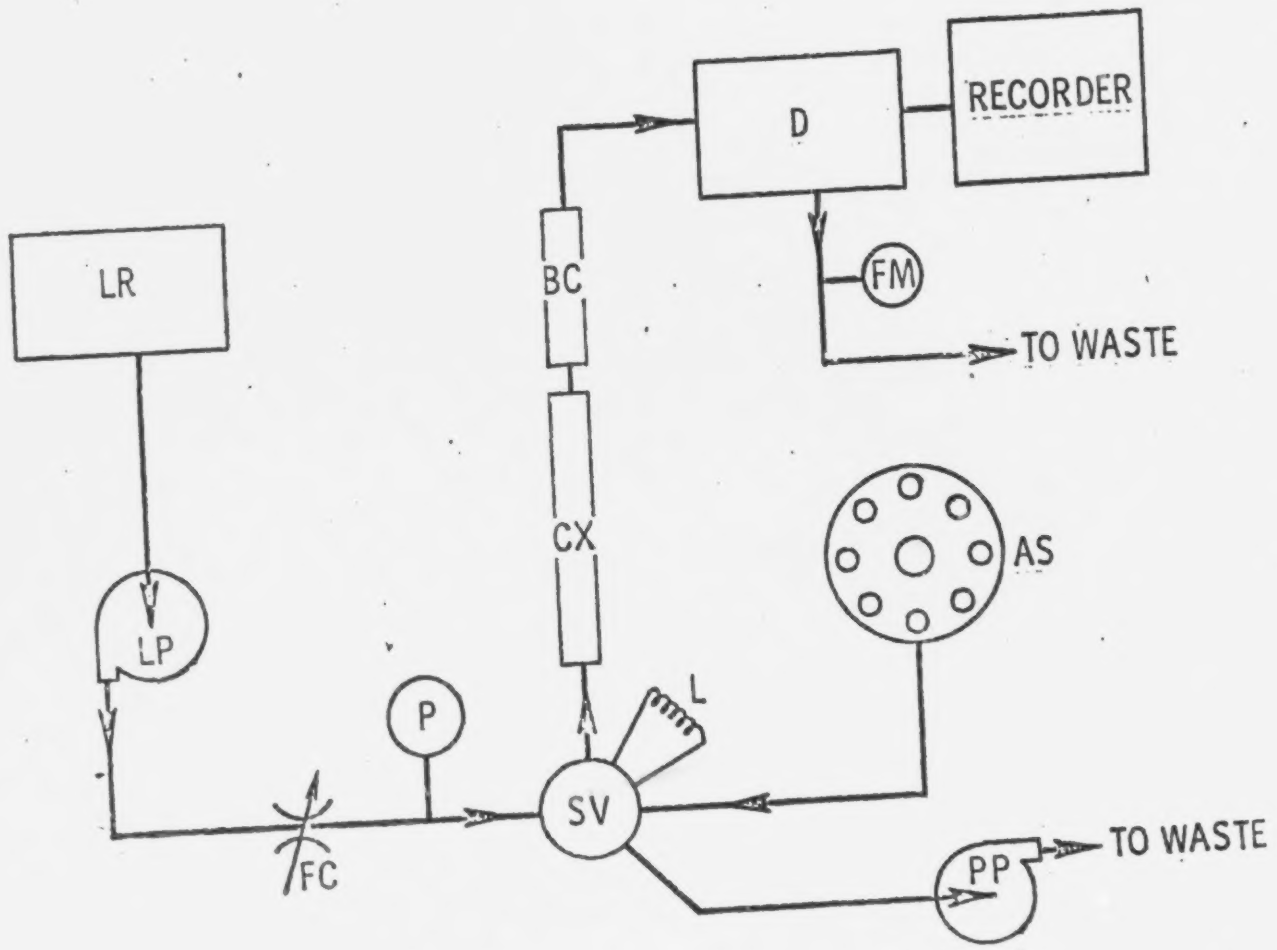
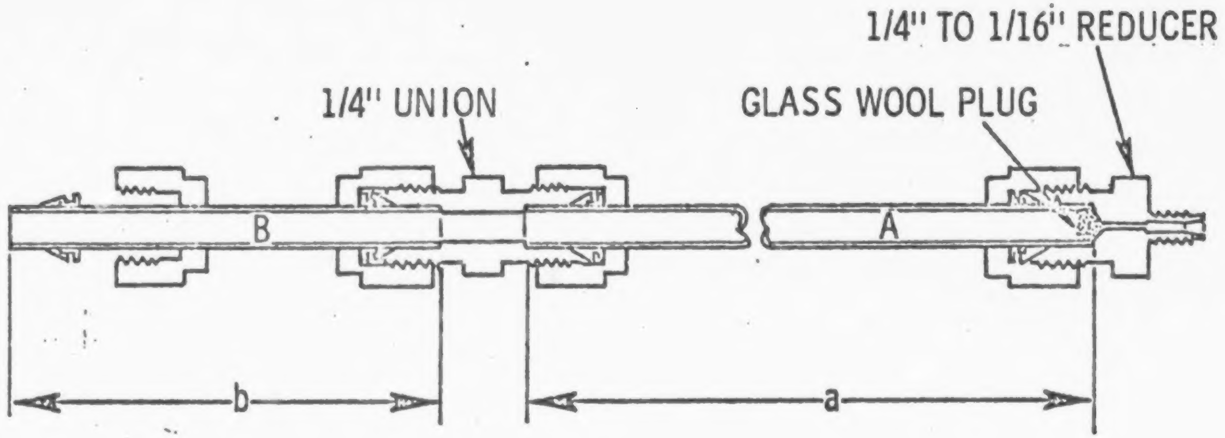

LR
LP
FC
P
SV
L
CX
BC
D
RECORDER
FM
TO WASTE
AS
PP
TO WASTE

FIGURE 2

CONFIGURATION FOR LOADING COLUMN


1/4" TO 1/16" REDUCER
1/4" UNION
GLASS WOOL PLUG
B
A
b
a

APPENDIX C

EMISSIONS CHARACTERIZATION DATA FOR MACK ETAY(B)673A CATERPILLAR 3208 w/EGR AND CHEVROLET 366 HEAVY-DUTY ENGINES

TABLE C-1. 21-MODE EPA EXP DIESEL EMISSION CYCLE

MACK-ETAY673 DIESEL ENGINE IN STANDARD CONFIGURATION-1000 HR CERT ENGINE
TEST 1 RUN 1 11-11-76 FUEL EM-239-F PROJECT 11-4623-001

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO	MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	600	0.0	0.0	.021	3.78	3.80	.006	1	260	301	213	0.00	R	R	R	12.6
2	1450	30.9	4.7	.074	9.45	9.52	.008	2	244	286	172	.34	14.43	33.75	33.27	12.6
3	1450	121.1	18.4	.115	9.75	9.86	.012	3	238	271	238	1.34	3.72	8.42	12.14	12.6
4	1450	270.6	41.1	.178	10.43	10.61	.017	4	232	214	392	2.51	1.74	3.20	9.64	12.6
5	1450	375.1	56.9	.231	10.63	10.87	.022	5	234	185	421	2.05	1.30	2.04	7.66	12.3
6	1450	750.2	113.9	.424	14.00	14.43	.031	6	180	221	676	8.31	.66	1.62	8.16	12.6
7	1450	1125.2	170.8	.620	17.68	18.30	.035	7	80	336	830	0.00	I	I	I	12.6
8	1450	1229.7	186.7	.671	18.40	19.07	.036	8	60	347	874	9.15	.18	2.06	8.50	12.6
9	1450	1379.2	209.4	.759	19.86	20.62	.038	9	44	385	905	0.00	I	I	I	12.6
10	1450	1497.9	227.4	.842	21.24	22.08	.039	10	34	308	926	0.00	I	I	I	12.3
11	600	0.0	0.0	.020	3.45	3.47	.006	11	184	191	268	0.00	R	R	R	12.3
12	1900	1227.3	244.2	.956	26.36	27.32	.036	12	60	257	688	7.81	.20	1.67	7.33	12.8
13	1900	1130.0	224.8	.872	25.63	26.51	.034	13	60	232	656	15.06	.21	1.59	7.37	12.8
14	1900	1006.5	200.2	.780	24.51	25.29	.032	14	64	220	596	8.61	.24	1.61	7.16	12.6
15	1900	921.1	183.2	.717	23.43	24.15	.031	15	76	181	565	13.38	.24	1.39	7.09	12.6
16	1900	614.8	122.3	.490	18.98	19.47	.026	16	140	118	442	8.93	.65	1.09	6.70	13.3
17	1900	306.2	60.9	.289	14.95	15.24	.019	17	208	159	268	0.00	I	I	I	13.1
18	1900	220.8	43.9	.234	14.32	14.55	.016	18	228	201	230	3.47	2.20	3.86	7.27	13.1
19	1900	97.3	19.4	.157	12.84	13.00	.012	19	274	243	160	0.00	I	I	I	13.1
20	1900	21.4	4.3	.112	12.10	12.21	.009	20	304	272	120	0.00	I	I	I	13.3
21	600	0.0	0.0	.018	3.78	3.80	.005	21	228	274	223	0.00	R	R	R	13.3

CYCLE COMPOSITE BSHC = .674 GRAM/KW HR
BSCO+ = 2.157 GRAM/KW HR
BSNO2++= 7.965 GRAM/KW HR
BSHC + BSNO2++= 8.639 GRAM/KW HR
BSFC = .246KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE C-2. 21-MODE EPA EXP DIESEL EMISSION CYCLE

MACK-ETAY673 DIESEL ENGINE IN STANDARD CONFIGURATION-1000 HR CERT ENGINE
TEST 1 RUN 2 11-11-76 FUEL EM-239-F PROJECT 11-4623-001

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO	MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	600	0.0	0.0	.021	3.79	3.81	.006	1	252	343	212	0.00	R	R	R	12.1
2	1450	28.5	4.3	.073	9.35	9.43	.008	2	240	314	177	.32	15.22	39.67	36.71	11.9
3	1450	121.1	18.4	.112	9.65	9.76	.012	3	244	271	246	1.34	3.77	8.35	12.45	11.9
4	1450	268.3	40.7	.178	9.90	10.08	.018	4	214	227	391	2.48	1.54	3.26	9.21	11.9
5	1450	370.3	56.2	.230	10.60	10.83	.022	5	236	185	422	2.02	1.32	2.07	7.74	11.4
6	1450	745.4	113.2	.423	13.85	14.27	.031	6	188	234	676	8.26	.64	1.71	8.12	11.1
7	1450	1115.7	169.4	.620	17.43	18.05	.036	7	90	348	833	0.00	I	I	I	11.6
8	1450	1220.2	185.3	.671	18.13	18.80	.037	8	68	374	875	9.08	.20	2.20	8.45	11.6
9	1450	1369.7	208.0	.758	19.55	20.31	.039	9	58	398	925	0.00	I	I	I	11.6
10	1450	1483.7	225.3	.823	21.06	21.88	.039	10	44	436	951	0.00	I	I	I	11.9
11	600	0.0	0.0	.020	3.48	3.49	.006	11	188	191	279	0.00	R	R	R	11.1
12	1900	1224.9	243.7	.956	26.15	27.10	.037	12	56	231	697	7.80	.18	1.49	7.38	11.6
13	1900	1127.6	224.3	.880	25.73	26.61	.034	13	44	232	662	15.03	.15	1.60	7.48	11.4
14	1900	1004.2	199.8	.786	24.34	25.13	.032	14	52	195	616	8.59	.19	1.42	7.37	11.9
15	1900	918.7	182.8	.720	23.36	24.08	.031	15	64	182	577	13.34	.25	1.39	7.24	11.4
16	1900	612.5	121.8	.496	19.15	19.64	.026	16	124	105	445	8.89	.58	.98	6.83	11.6
17	1900	306.2	60.9	.289	14.83	15.12	.019	17	200	133	270	0.00	I	I	I	11.2
18	1900	220.8	43.9	.234	13.84	14.07	.017	18	220	187	241	3.47	2.05	3.46	7.34	12.4
19	1900	97.3	19.4	.157	12.75	12.90	.012	19	266	243	167	0.00	I	I	I	12.4
20	1900	23.7	4.7	.112	11.95	12.07	.009	20	296	245	122	0.00	I	I	I	11.2
21	600	0.0	0.0	.018	3.72	3.74	.005	21	228	275	217	0.00	R	R	R	11.2

CYCLE COMPOSITE BSHC = .635 GRAM/KW HR
BSCO+ = 2.143 GRAM/KW HR
BSNO2++= 8.047 GRAM/KW HR
BSHC + BSNO2++= 8.683 GRAM/KW HR
BSFC = .247KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE C-3. 13-MODE FEDERAL DIESEL EMISSION CYCLE

MACK-ETAY673 DIESEL ENGINE IN STANDARD CONFIGURATION-1000 HR CERT ENGINE
TEST 1 RUN 1 11-11-76 FUEL EM-239-F PROJECT 11-4623-001

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	600	0,0	0,0	,021	3,68	3,70	,006
2	1450	30,9	4,7	,074	9,28	9,35	,008
3	1450	375,1	56,9	,231	10,47	10,70	,022
4	1450	750,2	113,9	,429	13,90	14,33	,031
5	1450	1125,2	170,8	,620	17,70	18,32	,035
6	1450	1497,9	227,4	,832	21,43	22,26	,039
7	600	0,0	0,0	,020	3,36	3,38	,006
8	1900	1227,3	244,2	,956	26,81	27,77	,036
9	1900	921,1	183,2	,717	23,72	24,43	,030
10	1900	614,8	122,3	,490	19,05	19,54	,026
11	1900	306,2	60,9	,299	14,87	15,16	,019
12	1900	21,4	4,3	,112	11,95	12,07	,009
13	600	0,0	0,0	,018	3,68	3,70	,005

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM, MILLI G/KG
1	260	301	198	0,00	R	R	R	12,6
2	244	286	170	,37	14,17	33,14	33,86	12,6
3	234	184	486	4,56	1,28	2,01	8,70	13,1
4	180	221	773	9,11	,66	1,61	9,26	12,6
5	80	336	893	13,67	,25	2,09	9,12	12,6
6	34	307	1004	18,19	,10	1,74	9,36	13,1
7	184	191	313	0,00	R	R	R	12,3
8	60	258	771	19,53	,20	1,70	8,35	12,8
9	140	181	660	14,66	,54	1,40	8,38	12,6
10	208	118	511	9,79	,97	1,09	7,77	13,1
11	228	159	318	4,87	1,65	2,29	7,54	13,1
12	304	272	133	,34	25,11	44,73	35,86	13,3
13	228	274	231	0,00	R	R	R	12,8

CYCLE COMPOSITE BSHC = ,683 GRAM/KW HR
BSCO+ = 2,084 GRAM/KW HR
BSNO2++= 9,038 GRAM/KW HR
BSHC + BSNO2++= 9,721 GRAM/KW HR
BSFC = ,242KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10,7 MILLIGRAMS WATER PER KG DRY AIR

TABLE C-4. 13-MODE FEDERAL DIESEL EMISSION CYCLE

MACK-ETAY673 DIESEL ENGINE IN STANDARD CONFIGURATION-1000 HR CERT ENGINE
EST 1 RUN 2 11-11-75 FUEL EM-239-F PROJECT 11-4623-001

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	600	0.0	0.0	.021	3.64	3.71	.006
2	1450	30.9	4.7	.073	9.19	9.26	.008
3	1450	372.7	56.6	.230	10.44	10.67	.022
4	1450	745.4	113.2	.423	13.75	14.17	.031
5	1450	1115.7	169.4	.620	17.45	18.07	.036
6	1450	1488.4	226.0	.823	21.25	22.07	.039
7	600	0.0	0.0	.020	3.38	3.40	.006
8	1900	1224.9	243.7	.956	26.60	27.55	.036
9	1900	918.7	182.8	.720	23.66	24.38	.030
10	1900	612.5	121.9	.496	19.23	19.72	.026
11	1900	306.2	60.9	.289	14.74	15.03	.020
12	1900	23.7	4.7	.112	11.81	11.92	.009
13	600	0.0	0.0	.018	3.62	3.64	.005

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM, MILLI G/KG
1	252	343	214	0.00	R	R	R	12.1
2	240	314	177	.37	13.80	35.95	33.27	11.9
3	236	185	458	4.53	1.29	2.02	8.21	12.1
4	188	234	736	9.05	.69	1.70	8.78	11.9
5	90	349	822	13.55	.28	2.16	8.35	11.6
6	44	437	1056	18.08	.13	2.47	9.82	11.9
7	188	191	319	0.00	R	R	R	12.1
8	56	231	715	19.50	.18	1.52	7.70	12.4
9	64	182	628	14.62	.25	1.41	7.98	11.4
10	124	105	497	9.75	.56	.99	7.67	11.6
11	200	133	296	4.87	1.44	1.90	6.95	11.2
12	296	245	117	.38	21.74	35.81	28.11	11.2
13	228	275	221	0.00	R	R	R	11.2

CYCLE COMPOSITE BSHC = .592 GRAM/KW HR
BSCO+ = 2.173 GRAM/KW HR
BSNO2++= 8.691 GRAM/KW HR
BSHC + BSNO2++= 9.283 GRAM/KW HR
BSFC = .243KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE C-5. 23-MODE EPA EXP DIESEL EMISSION CYCLE

PROJECT:11-4623-001 TEST DATE 6/1/77 RUN 1
ENGINE:CATERPILLAR 3208 W/EGR,S/N:40S3299A FUEL:EM-272-8

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	600	0.0	0.0	.016	2.18	2.20	.007
2	1680	11.9	2.1	.059	6.07	6.13	.010
3	1680	52.2	9.2	.080	6.01	6.09	.013
4	1680	116.3	20.5	.107	5.88	5.99	.018
5	1680	161.4	28.4	.132	5.86	5.99	.022
6	1680	322.9	56.8	.219	5.63	5.85	.039
7	1680	484.3	85.2	.311	6.82	7.13	.046
8	1680	529.4	93.1	.331	8.56	8.89	.039
9	1680	593.5	104.4	.371	8.56	8.93	.043
10	1680	655.2	115.3	.431	8.52	8.95	.051
11	600	0.0	0.0	.019	2.16	2.18	.007
12	1680	0.0	0.0	.002	5.80	5.80	.000
13	2800	498.5	146.2	.623	12.93	13.56	.049
14	2800	455.8	133.6	.558	12.93	13.49	.043
15	2800	405.9	119.0	.502	12.93	13.43	.039
16	2800	356.1	104.4	.485	10.16	10.65	.048
17	2800	237.4	69.6	.372	8.03	8.40	.046
18	2800	123.4	36.2	.245	8.41	8.65	.029
19	2800	90.2	26.4	.218	8.48	8.70	.026
20	2800	40.4	11.8	.173	8.51	8.68	.020
21	2800	9.5	2.8	.150	8.51	8.66	.018
22	600	0.0	0.0	.014	2.11	2.13	.006
23	2800	0.0	0.0	.014	8.76	8.77	.002

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	456	480	153	0.00	R	R	R	12.1
2	538	469	105	.13	45.98	79.91	29.47	12.1
3	534	474	134	.55	10.30	18.24	8.47	12.1
4	528	474	175	1.02	4.50	8.05	4.88	12.1
5	493	426	199	.85	3.03	5.21	3.99	12.1
6	520	304	230	3.41	1.56	1.82	2.26	12.1
7	420	386	627	0.00	I	I	I	12.1
8	290	135	1020	3.72	.81	.75	9.28	12.1
9	348	229	1020	0.00	I	I	I	12.1
10	224	916	980	0.00	I	I	I	12.1
11	368	386	171	0.00	R	R	R	12.1
12	96	24	8	0.00	R	R	R	12.1
13	100	1053	617	3.65	.27	5.66	5.45	12.1
14	162	892	608	7.35	.48	5.22	5.84	12.1
15	352	651	571	4.17	1.16	4.26	6.14	12.1
16	246	1853	336	6.26	.73	10.95	3.27	12.1
17	582	2097	173	4.18	2.04	14.68	1.99	12.1
18	470	957	164	0.00	I	I	I	12.1
19	518	808	145	1.72	4.96	15.40	4.55	12.1
20	598	684	117	0.00	I	I	I	12.1
21	686	702	100	0.00	I	I	I	12.1
22	418	405	143	0.00	R	R	R	12.1
23	208	35	7	0.00	R	R	R	12.1

CYCLE COMPOSITE BSHC = 1.857 GRAM/KW HR
BSCO+ = 7.798 GRAM/KW HR
BSNO2++= 5.186 GRAM/KW HR
BSHC + BSNO2++= 7.043 GRAM/KW HR
BSFC = .288KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS
WATER PER KG DRY AIR

TABLE C-6. 23-MODE EPA EXP DIESEL EMISSION CYCLE

PROJECT:11-4623-001 TEST DATE 6/1/77 RUN 2
ENGINE:CATERPILLAR 3208 W/EGR,S/N:40S3299A FUEL:EM-272-F

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	600	0.0	0.0	.014	2.21	2.22	.006
2	1680	11.9	2.1	.065	6.12	6.18	.011
3	1680	52.2	9.2	.079	6.05	6.13	.013
4	1680	116.3	20.5	.112	5.97	6.08	.019
5	1680	161.4	28.4	.133	5.85	5.98	.023
6	1680	322.9	56.8	.226	5.53	5.76	.041
7	1680	484.3	85.2	.313	6.76	7.08	.046
8	1680	529.4	93.1	.327	8.27	8.59	.040
9	1680	593.5	104.4	.377	8.39	8.77	.045
10	1680	645.7	113.6	.428	8.36	8.79	.051
11	600	0.0	0.0	.014	2.11	2.13	.006
12	1680	0.0	0.0	.001	5.74	5.74	.000
13	2800	493.8	144.8	.621	13.00	13.62	.048
14	2800	455.8	133.6	.566	12.92	13.48	.044
15	2800	405.9	119.0	.513	12.83	13.35	.040
16	2800	356.1	104.4	.500	10.00	10.50	.050
17	2800	237.4	69.6	.371	7.96	8.33	.047
18	2800	123.4	36.2	.246	8.29	8.54	.030
19	2800	90.2	26.4	.218	8.36	8.58	.026
20	2800	40.4	11.8	.172	8.39	8.56	.021
21	2800	9.5	2.8	.150	8.43	8.58	.018
22	600	0.0	0.0	.014	2.07	2.08	.007
23	2800	0.0	0.0	.010	8.75	8.76	.001

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	432	451	117	0.00	R	R	R	12.3
2	498	428	104	.13	42.90	73.44	29.25	12.3
3	512	426	124	.55	9.95	16.48	7.87	12.3
4	512	444	158	1.02	4.43	7.66	4.48	12.3
5	468	366	180	.85	2.87	4.47	3.60	12.3
6	516	285	219	3.41	1.52	1.68	2.12	12.3
7	514	485	579	0.00	I	I	I	12.3
8	320	124	953	3.72	.86	.66	8.37	12.3
9	348	252	963	0.00	I	I	I	12.3
10	204	902	935	0.00	I	I	I	12.3
11	394	383	164	0.00	R	R	R	12.3
12	84	24	9	0.00	R	R	R	12.3
13	76	1067	622	3.62	.21	5.82	5.58	12.3
14	116	941	607	7.35	.34	5.50	5.63	11.6
15	310	1123	557	4.17	1.01	7.30	5.95	11.6
16	176	2616	319	6.26	.52	15.25	3.05	11.6
17	516	2565	169	4.18	1.80	17.81	1.92	11.6
18	452	1020	161	0.00	I	I	I	11.6
19	516	860	136	1.72	4.87	16.17	4.20	11.6
20	632	684	110	0.00	I	I	I	11.6
21	712	728	88	0.00	I	I	I	11.6
22	439	408	131	0.00	R	R	R	11.6
23	188	40	7	0.00	R	R	R	11.6

CYCLE COMPOSITE BSHC = 1.708 GRAM/KW HR
BSCO+ = 9.228 GRAM/KW HR
BSNO2++= 4.958 GRAM/KW HR
BSHC + BSNO2++= 6.666 GRAM/KW HR
BSFC = .291KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS

TABLE C-7. 13-MODE FEDERAL DIESEL EMISSION CYCLE

PROJECT:11-4623-001 TEST DATE 6/1/77 RUN 1 (FACTORY TROUBLESHOOTER FIXED EGR)
ENGINE:CATERPILLAR 3208 W/EGR,S/N:40532999 FUEL EM-272-F

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	620	0.0	0.0	.016	2.18	2.20	.007
2	1680	11.9	2.1	.059	6.07	6.13	.010
3	1680	161.4	28.4	.132	5.86	5.99	.022
4	1680	322.9	56.8	.219	5.63	5.85	.039
5	1680	484.3	85.2	.311	6.82	7.13	.046
6	1680	655.2	115.3	.431	8.52	8.95	.051
7	620	0.0	0.0	.019	2.16	2.18	.007
8	2800	498.5	146.2	.629	12.93	13.56	.049
9	2800	356.1	104.4	.485	10.16	10.65	.048
10	2800	237.4	69.6	.372	8.03	8.40	.046
11	2800	123.4	36.2	.245	8.41	8.65	.029
12	2800	9.5	2.8	.150	8.51	8.66	.018
13	620	0.0	0.0	.014	2.11	2.13	.006

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	456	480	133	0.00	R	R	R	12.1
2	538	469	66	.17	45.98	79.91	18.38	12.1
3	493	426	185	2.27	3.03	5.21	3.71	12.1
4	520	304	264	4.54	1.56	1.82	2.58	12.1
5	420	386	668	6.82	1.02	1.87	5.33	12.1
6	224	916	1007	9.22	.51	4.12	7.45	12.1
7	368	386	167	0.00	R	R	R	12.1
8	100	1053	649	11.69	.27	5.66	5.73	12.1
9	246	1853	361	8.35	.73	10.95	3.50	12.1
10	584	2097	185	5.57	2.05	14.68	2.13	12.1
11	470	976	177	2.90	3.27	13.53	4.03	12.1
12	686	702	94	.22	62.08	126.54	27.76	12.1
13	418	405	131	0.00	R	R	R	12.1

CYCLE COMPOSITE BSHC = 1.594 GRAM/KW HR
BSCO+ = 7.763 GRAM/KW HR
BSNO2++= 5.027 GRAM/KW HR
BSHC + BSNO2++= 6.622 GRAM/KW HR
BSFC = .285KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE C-8. 13-MODE FEDERAL DIESEL EMISSION CYCLE

PROJECT:11-4623-001 TEST DATE 6/1/77 RUN 2
ENGINE:CATERPILLAR 3208 W/EGR S/N:40532998 FUEL:EM-272-F

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	620	0.0	0.0	.014	2.21	2.22	.006
2	1680	11.9	2.1	.065	6.12	6.18	.011
3	1680	161.4	28.4	.133	5.85	5.98	.023
4	1680	322.9	56.8	.226	5.53	5.76	.041
5	1680	484.3	85.2	.313	6.76	7.08	.046
6	1680	645.7	113.6	.428	8.36	8.79	.051
7	620	0.0	0.0	.019	2.11	2.13	.006
8	2800	493.8	144.8	.621	13.00	13.62	.048
9	2800	356.1	104.4	.500	10.00	10.50	.050
10	2800	237.4	69.6	.371	7.96	8.33	.047
11	2800	123.4	36.2	.246	8.24	8.54	.030
12	2000	9.5	2.8	.150	8.43	8.58	.018
13	620	0.0	0.0	.014	2.07	2.08	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	432	451	107	0.00	R	R	R	12.3
2	498	428	93	.17	42.90	73.44	26.35	12.3
3	468	366	205	2.27	2.87	4.47	4.12	12.3
4	516	285	276	4.54	1.52	1.68	2.66	12.3
5	514	485	656	6.82	1.24	2.34	5.19	12.3
6	204	902	955	9.09	.46	4.05	7.04	12.3
7	394	383	155	0.00	R	R	R	12.3
8	76	1067	670	11.58	.21	5.82	6.00	12.3
9	176	2613	358	8.35	.52	15.23	3.43	12.3
10	516	2562	190	5.57	1.80	17.79	2.16	12.3
11	452	1019	178	2.90	3.10	13.95	4.00	12.3
12	712	727	96	.22	63.87	129.92	28.14	12.3
13	439	407	121	0.00	R	R	R	12.3

CYCLE COMPOSITE BSHC = 1.524 GRAM/KW HR
BSCO+ = 8.856 GRAM/KW HR
BSNO2++= 5.019 GRAM/KW HR
BSHC + BSNO2++= 6.543 GRAM/KW HR
BSFC = .288KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

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                        TABLE  C-9. MASS EMISSIONS BY 23 MODE PROCEDURE
                        ENGINE-366TEST-123  RUN-1  REGULATED GASEOUS EMISSIONS ONLY
-------------------------------------------------------------------------------------
                  TQ             MV  FUEL     A/F              DRY CONCENTRATION
MODE SPEED       N-M     KW     MM  KG/HR    RATIO              HC      CO      CO2    NOX
-------------------------------------------------------------------------------------
  1    700       0.0      0    394    2.6    21.9             1396    .371     9.44     21
  2   1200      10.7      1    419    4.5    21.5               50    .128    10.05     54
  3   1200      28.5      4    401    4.9    21.1               53    .128    10.26     75
  4   1200      64.1      8    366    5.8    19.9               83    .200    10.80    119
  5   1200      87.2     11    333    6.4    19.4               88    .258    11.02    160
  6   1200     172.7     22    241    8.5    17.7              145    .577    11.81    400
  7   1200     259.9     33    124   11.9    16.0              180   1.086    12.64    475
  8   1200     284.8     36     76   12.7    15.6              203   1.410    12.64    610
  9   1200     320.4     40     23   14.2    15.2              317   1.790    12.64    690
 10   1200     345.4     43      3   15.9    13.9             1388   4.380    10.91    270
 11    700       0.0      0      0    2.6    21.3             1050    .389     9.74     21
 12   1200       0.0      0    531    2.8    25.3            11662    .172     7.09     11
 13   2300     364.9     88      3   34.9    12.9             1215   6.420     9.84     16
 14   2300     340.0     82     41   25.4    15.1               57   1.317    13.26    650
 15   2300     302.6     73     84   25.0    15.4               58    .979    13.38    740
 16   2300     275.9     66    124   23.2    15.8               35    .865    13.13    550
 17   2300     183.4     44    244   17.5    16.3                9    .144    13.51    380
 18   2300      92.6     22    366   12.5    17.1               15    .068    12.89    155
 19   2300      65.9     16    399   10.9    17.9                9    .072    12.28    116
 20   2300      30.3      7    442    8.5    20.3               19    .097    10.69    103
 21   2300       7.1      2    467    7.4    21.8               23    .092     9.95     70
 22    700       0.0      0    419    2.6    22.2             1568    .384     9.23     16
 23   2300       0.0      0    533    4.8    26.9             1373    .092     7.80     21
-------------------------------------------------------------------------------------
            CALCULATED GRAM/HR        WT.     E. UNITS    SPECIFIC GRAM/ KW-HR
MODE              HC      CO      NOX  FAC.      TQ    FC        HC       CO      NOX
-------------------------------------------------------------------------------------
  1             36.9     198      1.8  .070       0   5.8         R        R        R
  2              2.2     114      7.9  .060       8   9.9      1.65     85.1      5.9
  3              2.5     123     11.8  .060      21  10.9       .70     34.4      3.3
  4              4.4     213     20.8  .050      47  12.8       .54     26.4      2.6
  5              5.0     296     30.1  .030      64  14.1       .46     27.0      2.7
  6             10.0     801     91.3  .060     127  18.8       .46     36.9      4.2
  7             15.6    1897    136.4 0.000     192  26.2       .48     58.1      4.2
  8             18.4    2571    182.8  .040     210  28.0       .51     71.8      5.1
  9             31.1    3538    224.2 0.000     236  31.2       .77     87.9      5.6
 10            143.2    9130     92.5 0.000     255  35.1      3.30    210.4      2.1
 11             26.5     199      1.8  .070       0   5.7         R        R        R
 12            382.9     114      1.2  .120       0   6.1         R        R        R
 13            258.7   27614     11.3  .025     269  76.9      2.94    314.2       .1
 14              9.9    4642    376.6  .055     251  56.1       .12     56.7      4.6
 15             10.1    3442    427.4  .035     223  55.1       .14     47.2      5.9
 16              5.8    2894    302.3  .060     204  51.1       .09     43.6      4.5
 17              1.2     373    161.3  .060     135  38.5       .03      8.4      3.7
 18              1.4     132     49.5 0.000      68  27.5       .06      5.9      2.2
 19               .8     130     34.1  .065      49  24.1       .05      8.2      2.1
 20              1.5     155     27.0 0.000      22  18.8       .20     21.3      3.7
 21              1.7     137     17.1 0.000       5  16.3       .48     80.0     10.0
 22             42.2     209      1.4  .080       0   5.8         R        R        R
 23             81.5     111      4.1  .060       0  10.5         R        R        R

CYCLE COMPOSITE     HC      3.310    GRAM/ KW HR     ( 2.469 BS)
                    CO     73.497    GRAM/ KW HR     (54.807 BS)
                    NOX     3.997    GRAM/ KW HR     ( 2.981 BS)
                     SFC     .462      KG/ KW HR     (  .760 BS)
         CORRECTED NOX      4.405    GRAM/ KW HR     ( 3.284 BS)
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TABLE C-10. MASS EMISSIONS BY 23 MODE PROCEDURE
ENGINE-366TEST-123 RUN- 2 REGULATED GASEOUS EMISSIONS ONLY

MODE	SPEED	TQ N-M	KW	MV MM	FUEL KG/HR	A/F RATIO	DRY CONCENTRATION HC	CO	CO2	NOX
1	700	0.0	0	411	2.5	22.6	2781	.397	8.94	21
2	1200	8.9	1	414	4.4	21.7	57	.134	9.95	53
3	1200	28.5	4	399	5.0	21.2	82	.155	10.16	73
4	1200	62.3	8	358	5.6	20.6	82	.155	10.48	129
5	1200	87.2	11	330	6.2	19.9	108	.223	10.80	78
6	1200	174.5	22	241	8.7	17.7	100	.577	11.81	410
7	1200	261.7	33	122	12.2	15.8	198	1.181	12.76	415
8	1200	284.8	36	81	12.9	15.8	181	1.233	12.64	610
9	1200	320.4	40	28	14.3	15.7	226	1.479	12.52	710
10	1200	343.6	43	3	16.4	13.9	1515	4.540	10.69	260
11	700	0.0	0	432	2.6	21.3	1050	.397	9.74	15
12	1200	0.0	0	531	2.7	25.4	9850	.177	7.26	11
13	2300	363.2	87	3	34.2	13.4	1044	6.120	9.54	150
14	2300	340.0	82	41	27.7	15.4	66	1.410	12.89	600
15	2300	304.4	73	84	24.9	15.8	56	.940	13.01	740
16	2300	277.7	67	122	23.0	15.8	55	.884	13.13	600
17	2300	186.9	45	239	17.6	16.6	30	.128	13.26	390
18	2300	94.4	23	366	12.6	17.4	29	.068	12.64	158
19	2300	67.6	16	396	10.8	18.2	27	.072	12.05	125
20	2300	32.0	8	439	8.4	20.5	31	.102	10.58	110
21	2300	8.9	2	465	7.5	21.6	28	.092	10.05	77
22	700	0.0	0	406	2.4	23.2	5189	.410	8.36	3
23	2300	0.0	0	533	4.8	26.9	1442	.102	7.80	10

MODE	CALCULATED GRAM/HR HC	CO	NOX	WT. FAC.	E. UNITS TQ	FC	SPECIFIC GRAM/ KW-HR HC	CO	NOX
1	73.5	212	1.8	.070	0	5.6	R	R	R
2	2.5	116	7.6	.060	7	9.6	2.19	104.1	6.8
3	4.0	153	11.8	.060	21	11.1	1.12	42.7	3.3
4	4.4	166	22.6	.050	46	12.4	.56	21.1	2.9
5	6.1	253	14.6	.030	64	13.7	.55	23.1	1.3
6	7.0	815	95.1	.060	129	19.1	.32	37.2	4.3
7	17.3	2085	120.4	0.000	193	26.9	.53	63.4	3.7
8	16.8	2318	188.5	.040	210	28.5	.47	64.8	5.3
9	23.0	3044	240.2	0.000	236	31.5	.57	75.6	6.0
10	161.7	9790	92.1	0.000	253	36.2	3.75	226.7	2.1
11	26.5	202	1.3	.070	0	5.7	R	R	R
12	313.0	114	1.2	.120	0	5.9	R	R	R
13	226.5	26821	108.0	.025	268	75.4	2.59	306.6	1.2
14	12.7	5519	385.9	.055	251	61.1	.16	67.4	4.7
15	10.1	3388	438.4	.035	225	54.9	.14	46.2	6.0
16	4.1	2434	327.4	.060	205	50.8	.14	43.4	4.4
17	4.0	340	169.7	.060	138	38.7	.09	7.5	3.8
18	2.9	135	51.9	0.000	70	27.7	.13	5.9	2.3
19	2.4	131	37.1	.065	50	23.9	.15	8.0	2.3
20	2.4	163	28.8	0.000	24	18.6	.31	21.2	3.7
21	2.1	138	19.0	0.000	7	16.6	.98	64.5	8.9
22	131.8	210	.3	.080	0	5.2	R	R	R
23	85.4	122	2.0	.060	0	10.5	R	R	R

CYCLE COMPOSITE	HC	3.357	GRAM/ KW HR	(2.503 BS)
	CO	74.012	GRAM/ KW HR	(55.191 BS)
	NOX	4.234	GRAM/ KW HR	(3.157 BS)
	SFC	.463	KG/ KW HR	(.761 BS)
CORRECTED	NOX	4.701	GRAM/ KW HR	(3.505 BS)

TABLE C-11. SUMMARY OF EXHAUST PARTICULATE FROM MACK ETAY(B)673A (Based on 47 mm Glassfiber Filters)

Engine rpm load%	Date	Run No.	Concentration mg/M^3	Particulate Rate		
				g/hr	g/kg Fuel	g/kw-hr
1450	12/08/76	1	24.23	11.08	2.46	2.36
	12/21/76	2	21.84	10.05	2.09	2.14
		Avg.	23.04	10.57	2.28	2.25
1450	12/08/76	1	62.78	34.36	2.55	0.60
	12/21/76	2	60.00	32.66	2.40	0.55
		Avg.	61.39	33.51	2.48	0.58
1450	12/08/76	1	122.58	85.07	3.52	0.78
	12/21/76	2	114.40	83.75	3.30	0.71
		Avg.	118.49	84.41	3.41	0.75
1450	12/08/76	1	156.68	137.07	3.84	0.81
	12/21/76	2	137.14	128.61	3.48	0.73
		Avg.	146.91	132.84	3.66	0.77
1450	12/21/76	2	254.05	254.54	5.31	1.08
	01/03/77	3	255.04	266.97	5.48	1.14
		Avg.	254.55	260.76	5.40	1.11
Idle	12/07/76	1	12.36	2.29	1.91	(a)
	12/21/76	2	15.30	2.80	2.13	(a)
		Avg.	13.83	2.55	2.02	(a)
1900	12/22/76	2	143.78	205.55	3.64	0.81
	01/03/77	3	126.81	178.05	3.15	0.71
		Avg.	135.30	191.80	3.40	0.76
1900	12/22/76	2	103.01	125.82	2.91	0.65
	01/03/77	3	92.22	114.40	2.63	0.61
		Avg.	97.61	120.11	2.77	0.63
1900	12/07/76	1	89.73	87.02	2.96	0.71
	12/22/76	2	78.72	77.83	2.63	0.62
		Avg.	84.23	82.43	2.80	0.67
1900	12/07/76	1	74.43	55.56	3.31	0.90
	12/22/76	2	68.96	52.83	3.02	0.84
		Avg.	71.70	54.20	3.17	0.87
1900	12/07/76	1	36.33	22.25	3.13	4.73
	12/22/76	2	41.68	25.63	3.51	4.93
		Avg.	39.01	23.94	3.32	4.83

(a) no power output observed during idle and closed throttle

TABLE C-12. SUMMARY OF EXHAUST SO_4 FROM MACK ETAY(B)673A ENGINE
(Based on 47 mm Fluoropore Filters)

Engine rpm	Engine Load, %	Date	Run No.	Conc. µg/m³	Sulfate Rate			$SO_4^=$ as % Fuel S
					mg/hr	mg/kg fuel	mg/kw hr	
1450	02	12/08/76	1	1060.89	484.96	107.77	103.18	1.53
		12/21/76	2	803.78	369.81	77.04	78.68	1.09
			Avg	932.34	427.39	92.41	90.93	1.31
1450	25	12/08/76	1	4464.26	2443.50	177.47	42.94	2.52
		12/21/76	2	4401.84	2395.79	176.16	40.54	2.50
			Avg	4433.05	2419.65	176.82	41.74	2.51
1450	50	12/08/76	1	6455.16	4479.63	185.11	41.06	2.63
		12/21/76	2	6692.95	4899.55	192.90	41.45	2.74
			Avg	6574.06	4689.59	189.01	41.26	2.69
1450	75	12/08/76	1	6816.74	5963.14	167.03	35.20	2.37
		12/21/76	2	7169.16	6723.00	181.70	37.92	2.58
			Avg	6992.95	6343.07	174.37	36.56	2.48
1450	100	12/21/76	2	9418.86	9436.92	195.79	39.92	2.78
		01/03/77	3	9733.75	10189.09	209.22	43.49	2.97
			Avg	9576.31	9813.01	202.51	41.71	2.88
Idle		12/07/76	1	969.83	179.36	149.47	(a)	2.12
		12/21/76	2	928.02	169.52	141.27	(a)	2.00
			Avg	948.93	174.44	145.37	(a)	2.06
1900	100	12/22/76	2	9583.56	13701.00	242.50	54.26	3.44
		01/03/77	3	8124.67	11407.98	201.91	45.18	2.86
			Avg	8854.12	12554.49	222.21	49.72	3.15
1900	75	12/22/76	2	7501.68	9162.19	212.09	47.23	3.01
		01/03/77	3	5569.43	6911.01	158.87	36.59	2.25
			Avg	6535.56	8036.60	185.48	41.91	2.63
1900	50	12/07/76	1	6929.54	6719.87	228.57	54.72	3.24
		12/22/76	2	5041.51	4984.43	168.39	39.53	2.39
			Avg	5985.51	5852.15	198.48	47.13	2.82
1900	25	12/07/76	1	4600.44	3434.20	204.42	55.93	2.90
		12/22/76	2	4143.33	3174.10	181.38	50.54	2.57
			Avg	4371.89	3304.15	192.90	53.24	2.74
1900	02	12/07/76	1	1217.71	745.64	105.02	158.65	1.49
		12/22/76	2	1539.28	946.27	129.62	181.98	1.84
			Avg	1378.50	845.96	117.32	170.32	1.67

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[a] No power output observed during idle and closed throttle

TABLE C-13. SUMMARY OF EXHAUST PARTICULATE FROM CAT 3208/EGR ENGINE
(BASED ON 47 mm GLASSFIBER FILTERS)

Engine rpm	Engine Load, %	Date	Run No.	Concentration mg/m^3	Particulate Rate g/hr	g/kg Fuel	g/kW-hr
1680	02	6/24/77	1	47.34	14.62	3.75	6.96
		6/24/77	2	57.46	17.69	4.54	8.42
			Average	52.40	16.16	4.15	7.69
1680	25	6/23/77	1	58.23	17.69	2.16	0.62
		6/23/77	2	57.73	17.40	2.14	0.61
			Average	57.98	17.55	2.15	0.62
1680	50	6/22/77	1	209.75	60.53	4.42	1.07
		6/23/77	2	169.84	48.14	3.65	0.85
			Average	189.80	54.34	4.04	0.96
1680	75	6/22/77	1	328.17	118.19	6.00	1.39
		6/22/77	2	279.24	102.24	5.24	1.20
			Average	303.71	110.22	5.62	1.30
1680	100	6/17/77	1	463.27	207.69	8.11	1.83
		6/17/77	2	502.78	223.96	8.75	1.97
			Average	483.03	215.83	8.43	1.90
Idle		6/24/77	1	42.28	5.22	5.80	(a)
		6/24/77	2	32.99	3.97	4.96	(a)
			Average	37.64	4.60	5.38	(a)
1680	CT	6/27/77	1	60.92	19.85	(b)	(a)
		6/27/77	2	72.53	23.84	(b)	(a)
			Average	66.73	21.85	(b)	(a)
2800	100	6/16/77	1	405.59	267.55	7.10	1.87
		6/17/77	2	350.79	237.07	6.31	1.63
			Average	378.19	252.31	6.71	1.75
2800	75	6/17/77	1	1221.32	647.87	21.17	6.21
		6/17/77	2	1244.32	649.12	21.01	6.22
			Average	1232.82	648.50	21.09	6.22
2800	50	6/20/77	1	875.73	367.84	16.64	5.29
		6/20/77	2	963.72	398.29	17.70	5.72
			Average	919.73	383.07	17.17	5.51
2800	25	6/22/77	1	297.02	131.42	9.13	3.63
		6/22/77	2	307.34	135.49	9.28	3.74
			Average	302.18	133.46	9.21	3.69
2800	02	6/22/77	1	131.90	55.00	6.18	19.64
		6/22/77	2	122.23	59.02	6.56	21.08
			Average	127.07	57.01	6.37	20.36
2800	CT	4/29/77	1	63.71	26.22	(b)	(a)
		4/29/77	2	76.79	31.12	(b)	(a)
			Average	70.25	28.67	(b)	(a)

(a) No power output observed during idle and closed throttle

(b) No fuel consumed, therefore no emission rate calculated

TABLE C-14. SUMMARY OF EXHAUST $SO_4^=$ FROM CATERPILLAR 3208/EGR ENGINE
(BASED ON 47 mm FLUOROPORE FILTERS)

Engine rpm	Engine Load, %	Date	Run No.	Conc. mg/m^3	Sulfate Rate			$SO_4^=$ as % Fuel S
					mg/hr	mg/kg fuel	mg/kw-hr	
1680	2	6/24/77	1	774.1	239.20	62.29	113.90	0.883
		6/24/77	2	588.6	181.78	46.85	86.56	0.664
			Average	681.4	210.49	54.57	100.23	0.774
1680	25	6/23/77	1	1536.1	466.48	56.96	16.43	0.808
		6/23/77	2	1583.2	477.23	58.92	16.80	0.835
			Average	1559.7	471.85	57.94	16.61	0.822
1680	50	6/22/77	1	3265.1	944.85	69.02	16.63	0.979
		6/23/77	2	2684.9	760.93	57.78	13.40	0.819
			Average	2975.0	852.89	63.40	15.02	0.899
1680	75	6/22/77	1	3907.0	1407.07	71.94	16.51	1.020
		6/22/77	2	3672.4	1344.51	68.84	15.78	0.976
			Average	3789.7	1375.79	70.39	16.15	0.998
1680	100	6/17/77	1	3492.9	1565.89	61.14	13.76	0.867
		6/17/77	2	3669.9	1634.73	63.86	14.40	0.906
			Average	3581.4	1600.31	62.50	14.08	0.887
Idle		6/24/77	1	1706.8	206.60	232.13	(a)	3.292
		6/24/77	2	1635.7	196.68	223.50	(a)	3.169
			Average	1671.3	201.79	227.82	(a)	3.231
1680	CT	6/24/77	1	740.0	241.7	(b)	(a)	(b)
		6/27/77	2	871.4	286.4	(b)	(a)	(b)
			Average	805.7	264.1	(b)	(a)	(b)
2800	100	6/16/77	1	5159.0	3403.13	90.36	23.72	1.281
		6/17/77	2	5306.3	3586.04	95.37	24.72	1.352
			Average	5232.7	3494.59	92.87	23.22	1.317
2800	75	6/17/77	1	2915.8	1546.71	50.68	14.82	0.719
		6/17/77	2	3389.6	1768.27	57.37	16.94	0.814
			Average	3152.7	1657.49	54.03	15.88	0.767
2800	50	6/20/77	1	4110.6	1721.39	77.89	24.73	1.104
		6/20/77	2	4195.0	1735.53	76.93	24.94	1.091
			Average	4152.8	1728.46	77.41	24.84	1.098
2800	25	6/21/77	1	3754.6	1656.62	112.85	45.76	1.600
		6/22/77	2	4154.3	1831.34	125.61	50.59	1.781
			Average	3954.5	1743.98	119.23	48.18	1.691
2800	2	6/22/77	1	1747.0	786.14	88.23	280.76	1.251
		6/22/77	2	1721.9	770.42	85.79	275.15	1.217
			Average	1734.5	778.28	87.01	277.96	1.234
2800	CT	4/29/77	1	272.8	111.1	(b)	(a)	(b)
		4/29/77	2	520.9	211.1	(b)	(a)	(b)
			Average	396.9	161.1	(b)	(a)	(b)

(a) No power output observed during idle and closed throttle
(b) No fuel consumed, therefore no emission rate calculated

TABLE C-15. SUMMARY OF EXHAUST PARTICULATE FROM CHEVROLET 366 ENGINE
(BASED ON 47 mm GLASSFIBER FILTERS)

Engine rpm	Engine Load, %	Date	Run No.	Concentration mg/m^3	Particulate Rate g/hr	g/kg Fuel	g/kw-hr
1200	02	8/29/77	1	19.04	1.60	0.36	1.78
		8/29/77	2	21.78	1.83	0.43	2.03
			Average	20.41	1.72	0.40	1.91
1200	25	8/29/77	1	17.36	1.89	0.30	0.18
		8/29/77	2	18.66	2.03	0.32	0.18
			Average	18.01	1.96	0.31	0.18
1200	50	8/29/77	1	21.28	2.87	0.34	0.13
		8/30/77	2	23.69	3.20	0.38	0.15
			Average	22.49	3.04	0.36	0.14
1200	75	8/30/77	1	44.53	7.61	0.67	0.24
		8/30/77	2	35.84	6.12	0.53	0.19
			Average	40.19	6.87	0.60	0.22
1200	100	8/19/77	1	48.33	9.86	0.59	0.23
		8/19/77	2	50.38	10.28	0.61	0.25
			Average	49.36	10.07	0.60	0.24
Idle		8/26/77	1	27.06	1.30	0.52	(a)
		8/26/77	2	25.92	1.25	0.54	(a)
			Average	26.49	1.28	0.53	(a)
1200	CT	8/30/77	1	33.47	2.03	0.81	----
		8/30/77	2	28.11	1.70	0.68	----
			Average	30.79	1.87	0.75	
2300	100	8/19/77	1	65.37	26.84	0.79	0.30
		8/19/77	2	61.70	25.33	0.75	0.29
			Average	63.54	26.09	0.77	0.30
2300	75	8/19/77	1	58.13	18.87	0.81	0.29
		8/19/77	2	42.42	13.77	0.59	0.21
			Average	50.28	16.32	0.70	0.25
2300	50	8/19/77	1	23.49	6.02	0.34	0.14
		8/19/77	2	24.26	6.21	0.35	0.14
			Average	23.88	6.12	0.35	0.14
2300	25	8/22/77	1	25.24	4.86	0.41	0.22
		8/22/77	2	24.38	4.70	0.39	0.21
			Average	24.81	4.78	0.40	0.22
2300	02	8/23/77	1	15.48	2.20	0.31	1.29
		8/23/77	2	14.05	2.00	0.29	1.18
			Average	14.77	2.10	0.31	1.24
2300	CT	8/23/77	1	25.92	2.87	0.67	----
		8/23/77	2	24.40	2.70	0.63	----
			Average	25.16	2.79	0.65	----

(a) No power output observed during idle and closed throttle

TABLE C-16. SUMMARY OF EXHAUST SULFATE FROM CHEVROLET 366 ENGINE
(BASED ON INITIAL ANALYSES OF 47 mm FLUOROPORE FILTERS)

Engine rpm	Engine Load, %	Date	Run No.	Conc, $\mu g/m^3$	Sulfate Rate			$SO_4^=$ as % Fuel S
					mg/hr	mg/kg-fuel	mg/kW-hr	
1200	2	8/29/77	3	ND	-------	-------	---(a)	------
		8/29/77	4	ND	-------	-------	---(a)	------
			Average	ND	-------	-------	---(a)	------
1200	25	8/29/77	3	ND	-------	-------	------	------
		8/29/77	4	1.94	0.2103	0.0334	0.0197	0.0036
			Average	0.97	0.1052	0.0167	0.0099	0.0018
1200	50	8/30/77	3	4.70	0.6346	0.0744	0.0295	0.0081
		8/30/77	4	ND	-------	-------	------	------
			Average	2.35	0.3173	0.0372	0.0148	0.0041
1200	75	8/30/77	3	ND	-------	-------	------	------
		8/30/77	4	5.62	0.9597	0.0845	0.0296	0.0092
			Average	2.81	0.4799	0.0423	0.0148	0.0046
1200	100	8/19/77	3	10.01	7.5405	0.4529	0.1791	0.0493
		8/19/77	4	ND	-------	-------	------	------
			Average	5.01	3.7703	0.2265	0.0896	0.0247
Idle		8/26/77	3	ND	-------	-------	------	------
		8/26/77	4	16.87	0.8111	0.3511	------	0.0382
			Average	8.44	0.4056	0.1756	------	0.0191
1200	CT	8/30/77	3	74.12	4.4889	1.7673	---(a)	0.1924
		8/30/77	4	17.99	1.0898	0.4430	---(a)	0.0482
			Average	46.06	2.7894	1.1052	---(a)	0.1203
2300	100	8/19/77	3	ND	-------	-------	------	------
		8/19/77	4	422.88	173.6270	5.1022	1.9809	0.5553
			Average	211.44	86.8135	2.5511	0.9905	0.2777
2300	75	8/19/77	3	1365.07	443.1192	18.8963	6.6987	2.0567
		8/19/77	4	ND	-------	-------	------	------
			Average	[illegible]92.54	221.5596	9.4482	3.3494	1.0284
2300	50	8/19/77	3	116.14	3.0279	0.1707	0.0679	0.0186
		8/19/77	4	2.70	0.6903	0.0390	0.0155	0.0043
			Average	59.42	1.8591	0.1049	0.0417	0.0115
2300	25	8/22/77	3	ND	-------	-------	------	------
		8/22/77	4	ND	-------	-------	------	------
			Average	ND	-------	-------	------	------
2300	2	8/23/77	3	ND	-------	-------	------	------
		8/23/77	4	ND	-------	-------	------	------
			Average	ND	-------	-------	------	------
2300	CT	8/23/77	3	67.13	7.4313	1.7363	---(a)	0.1890
		8/23/77	4	70.43	7.7969	1.8260	---(a)	0.1988
			Average	68.78	7.6141	1.7812	---(a)	0.1937

ND Not detected, <0.3 $\mu g/m^3$, remaining values meaningless
(a) No power output observed during idle and closed throttle

TABLE C-17. SUMMARY OF EXHAUST SULFATE FROM CHEVROLET 366 ENGINE (BASED ON RE-ANALYZED SOLUTIONS[a] AND BACK-UP 37 mm FILTERS[b])

Engine rpm	Engine Load, %	Date	Run No.	Conc. ug/m^3	Sulfate Rate			$SO_4^=$ as % Fuel S
					mg/hr	mg/kg-fuel	mg/kW-hr	
1200	2	8/29/77	1	241.2	20.302	4.614	22.558	0.5126
		8/29/77	2	232.1	19.530	4.439	21.700	0.4932
			Average	236.7	19.916	11.527	22.129	0.5029
		8/29/77	2BU	0	16.831	3.825	18.701	0.4250
1200	25	8/29/77	1	191.9	20.850	3.310	1.949	0.3677
		8/29/77	2	185.9	20.195	3.206	1.887	0.3562
			Average	188.9	20.523	3.258	1.918	0.3620
		8/29/77	2BU	170.9	18.575	2.948	1.736	0.3276
1200	50	8/30/77	1	258.3	34.869	4.102	1.622	0.4557
		8/30/77	2	265.4	35.821	4.214	1.666	0.4682
			Average	261.9	35.345	4.158	1.644	0.4620
		8/30/77	2BU	273.0	36.853	4.336	1.714	0.4817
1200	75	8/30/77	1	479.7	81.944	7.126	2.561	0.7917
		8/30/77	2	465.7	79.651	6.918	2.486	0.7628
			Average	472.7	80.798	7.022	2.524	0.7773
		8/30/77	2BU	346.5	59.179	5.146	1.849	0.5717
1200	100	8/19/77	1	565.6	115.342	6.907	2.746	0.7674
		8/19/77	2	719.1	146.649	8.781	3.492	0.9756
			Average	642.4	130.996	7.844	3.119	0.8715
		8/19/77	2BU	608.2	124.024	7.427	2.953	0.8251
Idle		8/26/77	1	284.9	13.701	5.480	(c)	0.6088
		8/26/77	2	274.8	13.217	5.287	(c)	0.5874
			Average	279.9	13.459	5.384	(c)	0.5981
		8/26/77	2BU	294.1	14.142	5.657	(c)	0.6285
1200	CT	8/30/77	1	336.8	20.400	7.846	(c)	0.8717
		8/30/77	2	281.6	17.055	6.560	(c)	0.7288
			Average	309.2	18.728	7.203	(c)	0.8003
		8/30/77	2BU	239.1	14.481	5.570	(c)	0.6188
2300	100	8/19/77	1	965.6	396.465	11.730	4.510	1.3032
		8/19/77	2	2239.5	919.522	27.205	10.461	3.0225
			Average	1602.6	657.994	10.468	7.486	2.1629
		8/19/77	2BU	3086.5	1267.278	37.493	14.417	4.1655
2300	75	8/19/77	1	1969.3	639.261	27.203	9.627	3.0223
		8/19/77	2	1042.9	338.557	14.407	5.099	1.6006
			Average	1506.1	488.909	20.805	7.363	2.3115
		8/19/77	2BU	967.0	313.896	13.357	4.727	1.4840
2300	50	8/19/77	1	556.4	142.508	8.051	3.195	0.8945
		8/19/77	2	649.5	166.347	9.398	3.730	1.0441
			Average	603.0	154.428	8.725	3.463	0.9693
		8/19/77	2BU	464.1	118.849	6.715	2.665	0.7460
2300	25	8/22/77	1	562.0	108.245	9.020	4.943	1.0021
		8/22/77	2	490.5	94.459	7.872	4.313	0.8746
			Average	526.3	101.352	8.456	4.628	0.9384
		8/22/77	2BU	333.8	64.283	5.357	2.935	0.5952
2300	2	8/23/77	1	277.6	39.356	5.622	23.151	0.6246
		8/23/77	2	197.9	28.055	4.008	16.503	0.4453
			Average	237.8	33.706	4.815	19.827	0.5350
		8/23/77	2BU	72.9	10.341	1.477	6.083	0.1641
2300	CT	8/2377	1	199.3	22.068	5.132	(c)	0.5702
		8/23/77	2	272.2	30.128	7.006	(c)	0.7784
			Average	235.8	26.098	6.069	(c)	0.6743
		8/23/77	2BU	192.3	21.290	4.951	(c)	0.5501

(a) Re-analysis of IPA solutions performed 11/1/77, 9 weeks after initial analysis

(b) Back-up space filter originally ammoniated and placed into IPA solution on 10/28/77 and analyzed 10/28/77

(c) No power output observed during idle and closed throttle

TABLE C-18. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
MACK ETAY(B)673A, RUN 1
(13 MODE FTP WEIGHTING FACTORS)

								Weighted			
Mode	Engine rpm	Engine Load,%	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Power kW	Fuel kg/hr	Part g/hr	$SO_4^=$ mg/hr
1	Idle	---	-----	1.2	2.29	179.36	0.067	------	0.080	0.15	12.02
2	1450	2	4.7	4.5	11.08	484.96	0.08	0.376	0.36	0.89	38.80
3	1450	25	56.9	13.5	34.36	2443.50	0.08	4.552	1.08	2.75	195.48
4	1450	50	109.1	24.2	85.07	4479.63	0.08	8.728	1.94	6.81	358.37
5	1450	75	169.4	35.7	137.07	5963.14	0.08	13.55	2.86	10.97	477.05
6	1450	100	236.4	48.2	254.54	9436.92	0.08	18.91	3.86	20.36	754.95
7	Idle	---	-----	1.2	2.29	179.36	0.067	------	0.080	0.15	12.02
8	1900	100	252.5	56.5	205.55	13701.0	0.08	20.2	4.52	16.44	1096.08
9	1900	75	194.0	43.2	125.82	9162.19	0.08	15.52	3.46	10.07	732.98
10	1900	50	122.8	29.4	87.02	6719.87	0.08	9.82	2.35	6.96	537.59
11	1900	25	61.4	16.8	55.56	3434.20	0.08	4.91	1.34	4.44	274.74
12	1900	2	4.7	7.1	22.25	745.64	0.08	0.37	0.57	1.78	59.65
13	Idle	---	-----	1.2	2.29	179.36	0.067	-----	0.080	0.15	12.02
								96.94	22.58	81.92	4561.75

Brake Specific Particulate, g/kW-hr 0.845

Fuel Specific Particualte, g/kg fuel 3.628

Brake Specific $SO_4^=$, mg/kW-hr 47.05

Fuel Specific $SO_4^=$, mg/kg fuel 202.03

TABLE C-19.CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
MACK ETAY(B)673A, RUN 2
(13 MODE FTP WEIGHTING FACTORS)

								Weighted			
Mode	Engine rpm	Engine Load,%	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Power kW	Fuel kg/hr	Part g/hr	$SO_4^=$ mg/hr
1	Idle	---	-----	1.2	2.80	169.52	0.067	------	0.080	0.19	11.36
2	1450	2	4.7	4.8	10.05	369.81	0.08	0.376	0.384	0.80	29.58
3	1450	25	59.1	13.6	32.66	2395.79	0.08	4.728	1.088	2.61	191.66
4	1450	50	118.2	25.4	83.75	4899.55	0.08	0.456	2.032	6.70	391.96
5	1450	75	177.3	37.0	128.61	6723.0	0.08	14.181	2.96	10.29	537.84
6	1450	100	234.3	48.7	266.97	10189.09	0.08	18.744	3.896	21.36	815.13
7	Idle	---	-----	1.2	2.80	169.52	0.067	------	0.080	0.19	11.36
8	1900	100	252.2	56.5	178.05	11407.98	0.08	20.176	4.52	14.24	912.64
9	1900	75	188.9	43.5	114.40	6911.01	0.08	15.112	3.48	9.15	552.88
10	1900	50	126.1	29.6	77.83	4984.43	0.08	10.088	2.37	6.23	398.75
11	1900	25	62.8	17.5	52.83	3174.10	0.08	5.024	1.40	4.23	253.93
12	1900	2	5.2	7.3	25.63	946.27	0.08	0.416	0.58	2.05	75.70
13	Idle	---	-----	1.2	2.80	169.52	0.067	-----	0.080	0.19	11.36
								98.301	22.950	78.23	4194.15

Brake Specific Particulate, g/kW-hr 0.796

Fuel Specific Particulate, g/kg fuel 3.429

Brake Specific $SO_4^=$, mg/kW-hr 42.666

Fuel Specific $SO_4^=$, mg/kg fuel 182.752

TABLE C-20. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CATERPILLAR 3208/EGR, Run 1
(13-Mode FTP Weighting Factors)

								Weighted			
Mode No.	Engine rpm	Engine Load,%	Power KW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr
1	Idle		0	0.9	5.22	206.6	0.067	0	0.060	0.35	13.8
2	1680	2	2.1	3.9	14.62	239.2	0.08	0.168	0.312	1.17	19.1
3	1680	25	28.4	8.2	17.69	466.5	0.08	2.272	0.656	1.42	37.3
4	1680	50	56.8	13.7	60.53	944.8	0.08	4.544	1.096	4.84	75.6
5	1680	75	85.2	19.7	118.19	1407.1	0.08	6.816	1.576	9.46	112.6
6	1680	100	113.8	25.6	209.69	1565.9	0.08	9.104	2.048	16.62	125.3
7	Idle		0	0.9	5.22	206.6	0.067	0	0.060	0.35	13.8
8	2800	100	143.0	37.7	267.55	3403.1	0.08	11.440	3.016	21.40	272.3
9	2800	75	104.4	30.6	647.87	1546.7	0.08	8.352	2.448	51.83	123.7
10	2800	50	69.6	22.1	367.84	1721.4	0.08	5.568	1.768	29.43	137.7
11	2800	25	36.2	14.4	131.42	1656.6	0.08	2.900	1.152	10.51	132.5
12	2800	2	2.8	8.9	55.0	786.1	0.08	0.224	0.712	4.40	62.9
13	Idle		0	0.9	5.22	206.6	0.067	0	0.060	0.35	13.8
								51.388	14.964	152.13	1140.4

Brake specific particulate, g/kW-hr 2.96 Brake specific $SO_4^=$, mg/kW-hr 22.19

Fuel specific particulate, g/kg fuel 10.17 Fuel specific $SO_4^=$, mg/kg fuel 76.21

TABLE C-21. CYCLE COMPOSITE PARTICULATE AND SULFATE RESULTS
CATERPILLAR 3208/EGR, Run 2
(13-Mode FTP Weighting Factors)

								Weighted			
Mode No.	Engine rpm	Engine Load,%	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr
1	Idle		0	0.8	3.97	196.7	0.067	0	0.054	0.27	13.2
2	1680	2	2.1	3.9	17.69	181.8	0.08	0.168	0.312	1.42	14.5
3	1680	25	28.4	8.1	17.40	477.2	0.08	2.272	0.648	1.39	38.2
4	1680	50	56.8	13.2	48.14	760.9	0.08	4.544	1.056	3.85	60.9
5	1680	75	85.2	19.5	102.24	1344.5	0.08	6.816	1.560	8.18	107.6
6	1680	100	113.6	25.6	223.96	1634.7	0.08	9.088	2.048	17.92	130.8
7	Idle		0	0.8	3.97	196.7	0.067	0	0.054	0.27	13.2
8	2800	100	145.1	37.6	237.07	3586.0	0.08	11.608	3.008	18.97	286.9
9	2800	75	104.4	30.9	649.12	1768.3	0.08	8.352	2.472	51.93	141.5
10	2800	50	69.6	22.5	398.29	1735.5	0.08	5.568	1.80	31.86	138.8
11	2800	25	36.2	14.6	135.49	1831.3	0.08	2.896	1.168	10.8	146.5
12	2800	2	2.8	9.0	59.02	770.4	0.08	0.224	0.720	4.72	61.6
13	Idle		0	0.8	3.97	196.7	0.067	0	0.054	0.27	13.2
								51.542	14.954	151.85	1166.9

Brake specific particulate, g/kW-hr 2.95 Brake specific $SO_4^=$, mg/kW-hr 22.64

Fuel specific particulate, g/kg fuel 10.15 Fuel specific $SO_4^=$, mg/kg fuel 78.03

TABLE C-22. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CATERPILLAR 3208/EGR, RUN 1
(WEIGHTING FACTORS DERIVED FROM EPA 23-MODE TEST)

							Weighted			
Engine rpm	Engine Load, %	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr
Idle	---	-----	0.9	5.22	206.6	0.22	------	0.198	1.15	45.45
1680	2	2.1	3.9	14.62	239.2	0.12	0.252	0.468	1.75	28.70
	25	28.4	8.2	17.69	466.5	0.08	2.272	0.656	1.42	37.32
	50	56.8	13.7	60.53	944.8	0.06	3.408	0.822	3.63	56.69
	75	85.2	19.7	118.19	1407.1	0.04	3.408	0.788	4.73	56.28
	100	113.8	25.6	207.69	1565.9	0	------	-----	-----	------
	CT	0	0	19.85	241.7	0.12	------	-----	2.38	29.00
2800	100	143.0	37.7	267.55	3403.1	0.08	11.440	3.016	21.40	272.25
	75	104.4	30.6	647.87	1546.7	0.095	9.918	2.907	61.55	146.94
	50	69.6	22.1	367.84	1721.4	0.06	4.176	1.326	22.07	103.28
	25	36.2	14.4	131.42	1656.5	0.065	2.353	0.936	8.54	107.68
	2	2.8	8.9	55.0	786.1	0	------	-----	-----	------
	CT	0	0	26.22	111.1	0.06	------	-----	1.57	6.67
							37.227	11.117	130.19	809.26

Brake Specific Particulate, g/kW-hr	3.50	Brake Specific $SO_4^=$, mg/kW hr	23.91
Fuel Specific Particulate, g/kg fuel	11.71	Fuel Specific $SO_4^=$, mg/kg fuel	80.08

TABLE C-23. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CATERPILLAR 3208/EGR, Run 2
(WEIGHTING FACTORS DERIVED FROM EPA 23-MODE TEST)

							Weighted			
Engine rpm	Engine Load, %	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr
Idle	---	-----	0.8	3.97	196.7	0.22	------	0.176	0.87	43.27
1680	2	2.1	3.9	17.69	181.8	0.12	0.252	0.468	2.12	21.82
	25	28.4	8.1	17.40	477.2	0.08	2.272	0.648	1.39	38.18
	50	56.8	13.2	48.14	760.9	0.06	3.408	0.792	2.89	45.65
	75	85.2	19.5	102.24	1344.5	0.04	3.408	0.780	4.09	53.78
	100	113.6	25.6	223.96	1634.7	0	------	-----	-----	------
	CT	0	0	23.84	286.4	0.12	------	-----	2.86	34.37
2800	100	145.1	37.6	237.07	3586.0	0.08	11.608	3.008	18.97	286.88
	75	104.4	30.9	649.12	1768.3	0.095	9.918	2.936	61.67	167.99
	50	69.6	22.5	398.29	1735.5	0.06	4.176	1.350	23.90	104.13
	25	36.2	14.6	135.49	1831.3	0.065	2.353	0.949	8.81	119.03
	2	2.8	9.0	59.02	770.4	0	------	-----	-----	------
	CT	0	0	31.12	211.1	0.06	------	-----	1.87	12.67
							37.395	11.107	129.44	927.77

Brake Specific Particulate, g/kW-hr	3.46	Brake Specific $SO_4^=$, mg/kW hr	24.81
Fuel Specific Particulate, g/kg fuel	11.65	Fuel Specific $SO_4^=$, mg/kg fuel	83.53

TABLE C-24. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CHEVROLET 366, RUN 1
(13-MODE FTP WEIGHTING FACTORS)

									Weighted				
Mode	Engine rpm	Engine Load, %	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	$SO_4^=$(a) mg/hr	Wgt. Fact.	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	$SO_4^=$(a) mg/hr
1	Idle	---	----	2.5	1.30	0	13.701	0.067	------	0.17	0.087	0	0.918
2	1200	2	0.9	4.4	1.60	0	20.302	0.08	0.065	0.35	0.128	0	1.624
3	1200	25	10.7	6.3	1.89	0	20.850	0.08	0.856	0.50	0.151	0	1.668
4	1200	50	21.5	8.5	2.87	0.635	34.869	0.08	1.72	0.68	0.230	0.051	2.790
5	1200	75	32.0	11.4	7.61	0	81.944	0.08	2.56	0.91	0.609	0	6.556
6	1200	100	42.1	16.6	9.86	7.541	115.342	0.08	3.37	1.33	0.789	0.603	9.227
7	Idle	---	----	2.5	1.30	0	13.701	0.067	------	0.17	0.087	0	0.918
8	2300	100	88.3	33.6	26.84	0	396.465	0.08	7.06	2.69	2.147	0	31.717
9	2300	75	66.3	23.5	18.87	443.12	639.261	0.08	5.30	1.88	1.510	35.45	51.141
10	2300	50	44.6	17.7	6.02	3.028	142.508	0.08	3.57	1.42	0.482	0.242	11.401
11	2300	25	21.9	11.9	4.86	0	108.245	0.08	1.75	0.95	0.389	0	8.660
12	2300	2	1.7	7.0	2.20	0	39.356	0.08	0.14	0.56	0.176	0	3.148
13	Idle	---	----	2.5	1.30	0	13.701	0.067	------	0.17	0.087	0	0.918
									26.39	11.78	6.872	36.346	130.686

Brake Specific Particulate, g/kW-hr	0.260	
Fuel Specific Particulate, g/kg fuel	0.583	
Brake Specific $SO_4^=$, mg/kW-hr	1.377	4.952(a)
Fuel Specific $SO_4^=$, mg/kg fuel	3.085	11.094(a)

(a) Re-analysis of IPA solution nine weeks after initial analysis

TABLE C-25. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CHEVROLET 366, RUN 2
(13-MODE FTP WEIGHTING FACTORS)

										Weighted					
Mode	Engine rpm	Engine Load, %	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	$SO_4^=$(a) mg/hr	$SO_4^=$(b) mg/hr	Wgt. Fact.	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	$SO_4^=$(a) mg/hr	$SO_4^=$(b) mg/hr
1	Idle	---	----	2.4	1.25	0.8111	13.217	14.142	0.067	------	0.16	0.084	0.054	0.886	0.948
2	1200	2	0.9	4.3	1.83	0	19.530	16.831	0.08	0.072	0.34	0.146	0	1.562	1.346
3	1200	25	10.7	6.3	2.03	0.210	20.195	18.575	0.08	0.856	0.50	0.162	0.017	1.616	1.486
4	1200	50	21.5	8.4	3.20	0	35.821	36.853	0.08	1.72	0.67	0.256	0	2.866	2.948
5	1200	75	31.9	11.6	6.12	0.960	79.651	59.179	0.08	2.55	0.93	0.490	0.077	6.372	4.734
6	1200	100	41.8	16.8	10.29	0	146.649	124.024	0.08	3.34	1.34	0.823	0	11.732	9.922
7	Idle	---	----	2.4	1.25	0.8111	13.217	14.142	0.067	------	0.16	0.084	0.054	0.886	0.948
8	2300	100	87.5	34.0	25.33	173.627	919.522	1267.278	0.08	7.00	2.72	2.026	13.89	73.562	101.382
9	2300	75	66.5	23.5	13.71	0	338.557	313.896	0.08	5.32	1.88	1.097	0	27.085	25.112
10	2300	50	44.6	17.7	6.21	0.690	166.347	118.849	0.08	3.57	1.42	0.497	0.055	13.308	9.508
11	2300	25	21.9	12.1	4.70	0	94.459	64.283	0.08	1.75	0.97	0.376	0	7.557	5.143
12	2300	2	1.7	7.0	1.99	0	28.055	10.341	0.08	0.14	0.56	0.159	0	2.244	0.827
13	Idle	---	----	2.4	1.25	0.8111	13.217	14.142	0.067	------	0.16	0.084	0.054	0.886	0.948
										26.32	11.81	6.284	14.201	150.562	165.252

Brake Specific Particulate, g/kW-hr	0.239		
Fuel Specific Particulate, g/kg fuel	0.532		
Brake Specific $SO_4^=$, mg/kW-hr	0.540	5.720[(a)]	6.279[(b)]
Fuel Specific $SO_4^=$, mg/kg fuel	1.202	12.749[(a)]	13.993[(b)]

[(a)] Re-analysis of IPA solution nine weeks after initial analysis

[(b)] Back-up spare filter originally ammoniated, then placed into IPA solution and analyzed on 10/28/77

TABLE C-26. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CHEVROLET 366, RUN 1
(WEIGHTING FACTORS DERIVED FROM EPA 23-MODE TEST)

								Weighted				
Engine rpm	Engine Load, %	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	$SO_4^=$(a) mg/hr	Wgt. Fact.	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	$SO_4^=$(a) mg/hr
Idle	---	----	2.5	1.30	0	13.701	0.22	------	0.55	0.29	0	3.01
1200	2	0.9	4.4	1.60	0	20.302	0.12	0.108	0.53	0.19	0	2.44
1200	25	10.7	6.3	1.89	0	20.850	0.08	0.856	0.50	0.15	0	1.67
1200	50	21.5	8.5	2.87	0.635	34.869	0.06	1.29	0.51	0.17	0.038	2.09
1200	75	32.0	11.4	7.61	0	81.944	0.04	1.28	0.46	0.30	0	3.28
1200	100	42.1	16.6	9.86	7.541	115.342	0	------	----	----	------	------
1200	CT	----	2.6	2.03	4.489	20.400	0.12	------	0.31	0.24	0.539	2.45
2300	100	88.3	33.6	26.84	0	396.465	0.08	7.06	2.69	2.15	0	31.72
2300	75	66.3	23.5	18.87	443.12	639.261	0.095	6.30	2.23	1.79	42.096	60.73
2300	50	44.6	17.7	6.02	3.028	142.508	0.06	2.68	1.06	0.36	0.182	8.55
2300	25	21.9	11.9	4.86	0	108.245	0.065	1.42	0.77	0.32	0	7.04
2300	2	1.7	7.0	2.20	0	39.356	0	------	----	----	------	------
2300	CT	----	4.3	2.87	7.431	22.068	0.06	------	0.26	0.17	0.446	1.32
								20.99	9.87	6.13	43.301	124.30

Brake Specific Particulate, g/kW-hr	0.292	
Fuel Specific Particulate, g/kg fuel	0.621	
Brake Specific $SO_4^=$, mg/kW-hr	2.063	5.922(a)
Fuel Specific $SO_4^=$, mg/kg fuel	4.387	12.594(a)

(a) Re-analysis of IPA solutions nine weeks after initial analysis

TABLE C-27. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CHEVROLET 366, RUN 2
(WEIGHTING FACTORS DERIVED FROM EPA 23-MODE TEST)

									Weighted					
Engine rpm	Engine Load, %	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	$SO_4^=$(a) mg/hr	$SO_4^=$(b) mg/hr	Wgt. Fact.	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	$SO_4^=$(a) mg/hr	$SO_4^=$(b) mg/hr
Idle	---	----	2.4	1.25	0.811	13.217	14.142	0.22	------	0.528	0.275	0.178	3.11	2.91
1200	2	0.9	4.3	1.83	0	19.530	16.831	0.12	0.108	0.516	0.220	0	2.02	2.34
1200	25	10.7	6.3	2.03	0.210	20.195	18.575	0.08	0.856	0.504	0.162	0.017	1.49	1.62
1200	50	21.5	8.4	3.20	0	35.821	36.853	0.06	1.290	0.504	0.192	0	2.21	2.15
1200	75	31.9	11.6	6.12	0.960	79.651	59.179	0.04	1.276	0.464	0.245	0.038	2.37	3.19
1200	100	41.8	16.8	10.28	0	146.649	124.024	0	------	-----	-----	------	-------	-------
1200	CT	----	2.5	1.70	1.090	17.055	14.481	0.12	------	0.30	0.204	0.131	1.74	2.05
2300	100	87.5	34.0	25.33	173.627	919.522	1267.278	0.08	7.00	2.72	2.03	13.89	101.38	73.56
2300	75	66.5	23.5	13.77	0	338.557	313.896	0.095	6.32	2.23	1.31	0	29.82	32.16
2300	50	44.6	17.7	6.21	0.690	166.347	118.849	0.06	2.68	1.06	0.37	0.041	7.13	9.98
2300	25	21.9	12.1	4.70	0	94.459	64.283	0.065	1.42	0.79	0.30	0	4.18	6.14
2300	2	1.7	7.0	2.00	0	28.055	10.341	0	------	-----	-----	0	-------	-------
2300	CT	----	4.3	2.70	7.761	30.128	21.290	0.06	------	0.26	0.16	0.466	1.28	1.81
									20.95	9.88	5.47	14.761	156.730	137.91

Brake Specific Particulate, g/kW-hr	0.261		
Fuel Specific Particulate, g/kg fuel	0.554		
Brake Specific $SO_4^=$, mg/kW-hr	0.705	6.583(a)	7.48(b)
Fuel Specific $SO_4^=$, mg/kg fuel	1.494	13.959(a)	15.86(b)

(a) Re-analysis of IPA solutions nine weeks after initial analysis
(b) Back-up spare filter originally ammoniated, than placed into IPA solution and analyzed on 10/28/77

TABLE C-28.PARTICULATE AND BaP RATES FROM MACK ETAY(B)673A
(Based on 8 x 10 Size Fiberglass Filter Samples)

Engine rpm	Engine Load, %	Date	Run	Particulate Rates				BaP Rates				Organic Solubles %
				mg/m^3	g/hr	g/kg fuel	g/kW-hr	g/m^3	mg/hg	mg/kW-hr	mg/kg fuel	
1450	2	12/06/76	1	28.83	13.04	2.96	2.77	0.557	252.0	54.0	56.0	34.84
		12/22/76	2	25.36	11.48	2.55	2.44					
			Avg	27.10	12.26	2.76	2.61					
1450	50	12/06/76	1	100.18	69.69	2.94	0.62	0.647	481.0	4.0	18.0	9.3
		12/22/76	2	125.04	93.02	3.56	0.79					
			Avg	112.61	81.36	3.25	0.71					
1450	100	12/06/76	1	175.21	186.13	3.75	0.79	0.162	166.0	1.0	3.0	3.5
		12/22/76	2	188.87	193.77	3.98	0.82					
			Avg	182.04	189.95	3.87	0.81					
Idle		12/22/76	2	17.23	3.11	2.59	(1)	0.441	80.0	----	62.0	15.54
		01/03/77	3	18.53	3.34	1.96	(1)					
			Avg	17.88	3.23	2.28	(1)					
1900	100	12/06/76	1	120.12	171.01	3.02	0.68	0.162	229.0	1.0	4.0	1.02
		12/22/76	2	134.13	189.45	3.35	0.75					
			Avg	127.13	180.23	3.19	0.72					
1900	50	12/06/76	1	78.34	76.10	2.62	0.62	0.526	514.0	4.0	17.0	6.32
		01/03/77	2	68.04	66.55	2.21	0.52					
			Avg	73.19	71.33	2.42	0.57					
1900	2	12/22/76	1	27.15	16.65	2.16	3.20	0.494	303.0	58.0	40.0	38.46
		01/03/77	2	28.34	17.24	2.24	2.61					
			Avg	27.75	16.95	2.20	2.91					

(1) No power output observed

TABLE C-29. PARTICULATE AND BaP RATES FROM CAT 3208 EGR
(Based on 8 x 10 Size Fiberglass Filter Samples)

				Particulate Rates				BaP Rates				Organic
Engine rpm	Engine Load, %	Date	Run	mg/in^3	g/hr	g/kg fuel	g/kw-hr	μg/m^3	μg/hr	μg/kg fuel	μg/kw-hr	Solubles %
1680	2	6/27/77	6	90.67	27.90	6.975	13.286	0.152	46.9	11.7	22.3	21.72
		6/24/77	7	81.92	25.15	6.288	11.976	0.141	43.2	10.8	20.6	12.24
			Avg	86.30	26.53	6.631	12.631	0.147	45.1	11.3	21.5	16.98
1680	50	6/21/77	6	188.25	53.96	3.939	0.950	0.169	48.5	3.5	0.9	8.01
		6/21/77	7	188.06	53.43	3.900	0.941	0.062	17.6	1.3	0.3	5.31
			Avg	188.16	53.70	3.920	0.945	0.116	33.1	2.4	0.6	6.66
1680	100	6/16/77	6	413.53	183.09	7.180	1.606	Below minimum detectable				2.51
		6/16/77	7	444.96	197.44	7.713	1.744	Below minimum detectable				2.93
			Avg	429.25	190.27	7.446	1.675					2.72
Idle		6/27/77	6	37.64	4.41	4.900	(1)	0.221	24.3	27.0	(1)	8.17
		6/27/77	7	45.25	5.34	5.933	(1)	0.199	23.4	26.0	(1)	8.21
			Avg	41.45	4.88	5.417	(1)	0.210	23.9	27.0	(1)	8.19
1680	CT	5/03/77	4	116.01	30.96	(2)	(1)	0.167	44.5	(2)	(1)	32.19
		5/05/77	5	66.33	17.90	(2)	(1)	0.071	19.3	(2)	(1)	14.47
			Avg	91.17	24.43	(2)	(1)	0.119	31.9	(2)	(1)	23.33
2800	100	6/16/77	6	338.45	229.19	6.031	1.575	Below minimum detectable				2.52
		6/16/77	7	342.88	230.84	6.123	1.594	Below minimum detectable				2.90
			Avg	340.67	230.02	6.077	1.585					2.71
2800	50	6/21/77	6	773.97	324.99	14.192	4.669	1.946	817.3	35.7	11.7	2.13
		6/21/77	7	1036.73	435.33	19.262	6.345	1.389	583.1	25.8	8.4	2.23
			Avg	905.35	380.16	16.727	5.507	1.668	700.2	30.8	10.1	2.18
2800	2	6/21/77	6	114.69	52.40	5.758	14.971	0.190	86.7	9.5	24.8	6.86
		6/21/77	7	119.15	54.53	5.992	15.580	0.196	89.5	9.8	25.6	11.91
			Avg	116.92	53.47	5.875	15.276	0.193	88.1	9.7	25.2	9.39
2800	CT	6/27/77	6	73.32	33.86	(2)	(1)	0.112	51.3	(2)	(1)	16.31
		6/27/77	7	70.95	33.08	(2)	(1)	0.103	47.8	(2)	(1)	31.03
			Avg	72.14	33.38	(2)	(1)	0.108	49.6	(2)	(1)	23.67

(1) No power output observed
(2) No fuel consumption measurable

TABLE C-30. PARTICULATE AND BaP RATES FROM CHEVROLET 366
(Based on 8 x 10 Size Fiberglass Filter Samples)

				Particulate Rates				BaP Rates				Organic Solubles
Engine rpm	Engine load, %	Date	Run	$\frac{mg}{m^3}$	$\frac{g}{hr}$	$\frac{g}{kg\ fuel}$	$\frac{g}{kw\text{-}hr}$	$\frac{\mu g}{m^3}$	$\frac{mg}{hr}$	$\frac{mg}{kg\ fuel}$	$\frac{mg}{kw\text{-}hr}$	%*
1200	2	8/25/77	1	13.4	1.13	0.257	1.256	Below Minimum Detectable				2.40
		8/25/77	2	14.3	1.21	0.275	1.344					
			Avg	13.9	1.17	0.266	1.300					
1200	50	8/25/77	1	13.64	1.84	0.222	0.090	0.0093	1.3	0.2	0.1	3.99
		8/25/77	2	12.80	1.73	0.211	0.085					
			Avg	13.22	1.79	0.217	0.088					
1200	100	8/18/77	1	52.58	10.72	0.634	0.255	1.9138	390.2	23.2	9.3	2.02
		8/18/88	2	52.45	10.70	0.633	0.254					
			Avg	52.52	10.71	0.634	0.255					
Idle		8/24/77	1	14.89	0.72	0.300	(1)	Below Minimum Detectable				6.05
		8/25/77	2	15.00	0.72	0.277	(1)					
			Avg	14.95	0.72	0.289	(1)					
1200	CT	8/26/77	1	18.06	1.09	0.389	(1)	0.0117	0.7	0.3	-----	5.63
		8/26/77	2	18.27	1.11	0.396	(1)					
			Avg	18.17	1.10	0.393	(1)					
2300	2	8/23/77	1	23.65	3.35	0.465	1.970	0.0159	6.5	0.2	0.1	1.74
		8/24/77	2	17.12	2.43	0.338	1.429					
			Avg	20.39	2.89	0.402	1.700					
2300	50	8/18/77	1	22.88	5.86	0.335	0.134	0.1082	27.7	1.6	0.6	2.62
		8/18/77	2	22.43	5.74	0.326	0.131					
			Avg	22.66	5.80	0.331	0.133					
2300	100	8/18/77	1	67.90	27.88	0.825	0.316	2.045	289.9	40.3	170.5	3.90
		8/18/77	2	62.08	25.49	0.752	0.289					
			Avg	64.99	26.69	0.789	0.303					
2300	CT	8/24/77	1	34.22	3.79	0.861	(1)	0.0292	3.2	0.7	-----	2.87
		8/24/77	2	26.28	2.91	0.676	(1)					
			Avg	30.25	3.35	0.769						

* Determined as organic solubles in benzene by RTP

(1) No power output observed

TABLE C-31. BRAKE AND FUEL SPECIFIC BaP RATES - 7-MODE CYCLE
Mack ETAY(B)763A

						W. F. Derived from 13-mode FTP				W. F. Derived from 23-mode EPA			
Mode No.	Engine rpm	Engine load,%	Power kW	Fuel kg/hr	BaP µg/hr	Wgt Fact	Power kW	Fuel kg/hr	BaP µg/hr	Wgt Fact	Power kW	Fuel kg/hr	BaP µg/hr
1	1450	2	4.7	4.5	252.0	0.12	0.564	0.540	30.24	.225	1.058	1.013	56.700
2	1450	50	118.2	26.1	481.0	0.16	18.912	4.176	76.96	.092	10.874	2.401	44.252
3	1450	100	236.4	48.7	166.0	0.12	28.368	5.844	19.92	.049	11.584	2.386	8.134
4	Idle		-----	1.3	80.0	0.20	------	0.260	16.00	.269	------	0.350	21.520
5	1900	100	252.2	56.4	229.0	0.12	30.264	6.768	27.48	.176	44.387	9.926	40.304
6	1900	50	127.5	30.2	514.0	0.16	20.400	4.832	82.24	.110	14.025	3.322	56.540
7	1900	2	5.2	7.6	303.0	0.12	0.624	0.912	36.36	.079	0.411	0.600	23.937
							99.132	23.332	289.20		82.339	19.998	251.387
Brake Specific BaP, µg/kW-hr								2.917				3.053	
Fuel Specific BaP, µg/kg fuel								12.395				12.571	

TABLE C-32. BRAKE AND FUEL SPECIFIC BaP RATE - 7-MODE CYCLE
Cat 3208/EGR (Run 1)

						W. F. Derived from 13-mode FTP				W. F. Derived from 23-mode EPA			
Mode No.	Engine rpm	Engine load,%	Power kW	Fuel kg/hr	BaP µg/hr	Wgt Fact	Power kW	Fuel kg/hr	BaP µg/hr	Wgt Fact	Power kW	Fuel kg/hr	Bap µg/hr
1	1680	2	2.1	4.0	46.9	0.12	0.252	0.480	5.628	0.225	0.473	0.900	10.553
2	1680	50	56.8	13.7	48.5	0.16	9.088	2.192	7.760	0.092	5.226	1.260	4.462
3	1680	100	114.0	25.5	-----	0.12	13.680	3.060	-------	0.049	5.586	1.250	-------
4	Idle		0	0.9	24.3	0.20	------	0.18	4.860	0.269	------	0.242	6.537
5	2800	100	145.5	38.0	-----	0.12	17.460	4.560	-------	0.176	25.608	6.688	-------
6	2800	50	69.6	22.9	817.3	0.16	11.136	3.664	130.768	0.110	7.656	2.519	89.903
7	2800	2	3.5	9.1	86.7	0.12	0.420	1.092	10.404	0.079	0.277	0.719	6.849
							52.036	15.228	159.420		44.826	13.578	118.304
Brake Specific BaP, µg/kW-hr								3.064				2.639	
Fuel Specific BaP, µg/kg fuel								10.469				8.713	

TABLE C-33. BRAKE AND FUEL SPECIFIC BaP RATES - 7-MODE CYCLE

Cat 3208/EGR (Run 2)

						W. F. Derived from 1 -mode FTP				W. F. Derived from 23-mode EPA			
Mode No.	Engine rpm	Engine load,%	Power kW	Fuel kg/hr	BaP µg/hr	Wgt Fact	Power kW	Fuel kg/hr	Bap µg/hr	Wgt Fact	Power kW	Fuel kg/hr	Bap µg/hr
1	1680	2	2.1	4.0	43.2	.12	0.252	0.480	5.184	0.225	0.473	0.900	9.720
2	1680	50	56.8	13.7	17.6	.16	9.088	2.192	2.816	0.092	5.226	1.260	1.619
3	1680	100	113.2	25.6	-----	.12	13.584	3.072	------	0.049	5.547	1.254	------
4	Idle		-----	0.9	23.4	.20	------	0.18	4.680	0.269	------	0.242	6.295
5	2800	100	144.8	37.7	-----	.12	17.376	4.524	------	0.176	25.485	6.635	------
6	2800	50	69.6	22.6	583.1	.16	11.136	3.616	93.296	0.110	7.656	2.486	64.141
7	2800	2	3.5	9.1	89.5	.12	0.420	1.092	10.74	0.079	0.277	0.719	7.071
							51.856	15.156	116.716		44.664	13.496	88.846
Brake Specific BaP, µg/kW-hr								2.251				1.989	
Fuel Specific BaP, µg/kg fuel								7.701				6.583	

TABLE C-34. BRAKE AND FUEL SPECIFIC BaP RATE - 9-MODE CYCLE
Cat. 3208/EGR (Run 1)

Mode No.	Engine rpm	Engine Load, %	Power kW	Fuel kg/hr	BaP µg/hr	Wgt. Fact.	Weighted Power kW	Weighted Fuel kg/hr	Weighted BaP µg/hr
1	Idle		----	0.9	24.3	0.220	------	0.198	5.346
2	1680	2	2.1	4.0	46.9	0.185	0.389	0.188	8.677
3	1680	50	56.8	13.7	48.5	0.075	4.26	1.028	3.638
4	1680	100	114.0	25.5	----	0.040	4.56	1.02	-----
5	1680	CT	0	0	44.5	0.120	------	-----	5.340
6	2800	100	145.5	38.0	----	0.145	21.098	5.51	-----
7	2800	50	69.6	22.9	817.3	0.09	6.264	2.061	73.557
8	2800	2	3.5	9.1	86.7	0.965	0.228	0.592	5.636
9	2800	CT	0	0	51.3	0.6	------	-----	3.078
							36.799	10.597	105.272

Brake Specific BaP, µg/kW-hr 2.861
Fuel Specific BaP, µg/kg fuel 9.934

TABLE C-35. BRAKE AND FUEL SPECIFIC BaP RATES - 9-MODE CYCLE
Cat. 3208/EGR (Run 2)

Mode No.	Engine rpm	Engine Load, %	Power, kW	Fuel kg/hr	BaP µg/hr	Wgt. Fact.	Power kW	Fuel kg/hr	BaP µg/hr
1	Idle		0	0.9	23.4	0.220	------	0.198	5.148
2	1680	2	2.1	4.0	43.2	0.185	0.389	0.74	7.992
3	1680	50	56.8	13.7	17.6	0.075	4.260	1.028	1.320
4	1680	100	113.2	25.6	----	0.040	4.528	1.024	-----
5	1680	CT	0	0	19.3	0.120	------	-----	2.316
6	2800	100	144.8	37.7	----	0.145	20.996	5.467	-----
7	2800	50	69.6	22.6	583.1	0.090	6.264	2.034	52.479
8	2800	2	3.5	9.1	89.5	0.065	0.228	0.592	5.818
9	2800	CT	0	0	47.8	0.06	------	-----	2.868
							36.665	11.083	77.941

Brake Specific BaP, µg/kW-hr 2.126
Fuel Specific BaP, µg/kg fuel 7.032

TABLE C-36. BRAKE AND FUEL SPECIFIC BaP RATES - 7-MODE CYCLE
Chev 366

						W. F. Derived from 13-mode FTP				W. F. Derived from 23-mode EPA			
Mode No.	Engine rpm	Engine load,%	Power kW	Fuel kg/hr	BaP µg/hr	Wgt Fact	Power kW	Fuel kg/hr	BaP µg/hr	Wgt Fact	Power kW	Fuel kg/hr	BaP µg/hr
1	1200	2	----	-----	-----	.12	------	------	------	0.225	------	------	-------
2	1200	50	20.4	8.3	1.3	.16	3.264	1.328	0.208	0.092	1.877	0.764	0.120
3	1200	100	42.1	16.8	390.2	.12	5.052	2.016	46.824	0.049	2.063	0.823	19.120
4	Idle		----	----	-----	.20	------	------	------	0.269	------	------	-------
5	2300	100	88.5	34.0	289.9	.12	10.620	4.080	34.788	0.176	15.576	5.984	51.022
6	2300	50	43.7	17.6	27.7	.16	6.992	2.816	4.432	0.110	4.807	1.936	3.047
7	2300	2	1.7	7.2	6.5	.12	0.204	0.864	0.780	0.079	0.134	0.569	0.514
							26.132	11.104	87.032		24.457	10.076	73.823
Brake Specific BaP, µg/kW·hr								3.330				3.018	
Fuel Specific BaP, µg/kg fuel								7.838				7.327	

TABLE C-37. BRAKE AND FUEL SPECIFIC BaP RATES - 9-MODE CYCLE
Chevrolet 366

							Weighted		
Mode No.	Engine rpm	Engine Load, %	Power kW	Fuel kg/hr	BaP µg/hr	Wgt. Fact.	Power kW	Fuel kg/hr	BaP µg/hr
1	Idle		----	----	-----	.220	------	-----	------
2	1200	2	----	----	-----	.185	------	-----	------
3	1200	50	20.4	8.3	1.3	.075	1.530	0.623	0.098
4	1200	100	42.1	16.8	390.2	.040	1.684	0.672	15.608
5	1200	CT	----	2.8	0.7	.120	------	0.336	0.084
6	2300	100	88.5	34.0	289.9	.145	12.833	4.930	42.036
7	2300	50	43.7	17.6	27.7	.090	3.933	1.584	2.493
8	2300	2	1.7	7.2	6.5	.065	0.111	0.468	0.423
9	2300	CT	----	4.4	3.2	.06	------	0.264	0.192
							20.091	8.877	60.934

Brake Specific BaP, µg/kW-hr 3.033
Fuel Specific BaP, µg/kg fuel 6.864

TABLE C-38. COMPARISON OF ODOR RATINGS - MACK ETAY(B)673A

Operating Condition	Date	"D" Composite	"B" Burnt	"O" Oily	"A" Aromatic	"P" Pungent
Inter. Speed	2/01/77	2.7	1.0	0.9	0.8	0.4
2% Load	2/03/77	3.0	1.0	0.9	0.8	0.5
	Average	2.9	1.0	0.9	0.8	0.5
Inter. Speed	2/01/77	2.6	1.0	0.9	0.7	0.3
50% Load	2/03/77	2.5	1.0	0.9	0.7	0.4
	Average	2.6	1.0	0.9	0.7	0.4
Inter. Speed	2/01/77	3.1	1.0	1.0	0.9	0.7
100% Load	2/03/77	3.3	1.0	1.0	1.0	0.6
	Average	3.2	1.0	1.0	1.0	0.7
High Speed	2/01/77	3.2	1.0	1.0	0.9	0.5
2% Load	2/03/77	3.1	1.0	1.0	0.8	0.6
	Average	3.2	1.0	1.0	0.9	0.6
High Speed	2/01/77	2.8	0.9	0.9	0.9	0.4
50% Load	2/03/77	2.9	1.0	1.0	0.8	0.5
	Average	2.9	1.0	1.0	0.9	0.5
High Speed	2/01/77	3.2	1.0	1.0	0.8	0.7
100% Load	2/03/77	3.4	1.1	1.0	0.8	0.8
	Average	3.3	1.1	1.0	0.8	0.8
Idle	2/01/77	3.4	1.0	1.0	1.0	0.7
	2/03/77	3.6	1.0	1.0	0.9	0.8
	Average	3.5	1.0	1.0	1.0	0.8
Idle-Accel	2/01/77	2.9	1.0	0.9	0.7	0.6
	2/03/77	3.2	1.0	1.0	0.7	0.8
	Average	3.1	1.0	1.0	0.7	0.7
Acceleration	2/01/77	3.2	1.0	0.9	0.9	0.7
	2/03/77	3.1	1.0	1.0	0.7	0.6
	Average	3.2	1.0	1.0	0.8	0.7
Deceleration	2/01/77	2.6	1.0	0.9	0.6	0.5
	2/03/77	2.8	1.0	1.0	0.6	0.5
	Average	2.7	1.0	1.0	0.6	0.5
Cold Start	2/01/77	4.6	1.6	1.0	1.0	1.0
	2/03/77	4.1	1.3	1.0	1.0	0.9
	Average	4.4	1.5	1.0	1.0	1.0

TABLE C-39. ODOR EVALUATION SUMMARY

Engine: Mack ETAY(B)673A

Date: February 1, 1977

Run No.	Operating Condition	"D" Composite	"B" Burnt	"O" Oily	"A" Aromatic	"P" Pungent
6.	Inter.Speed 2% Load	2.7	1.0	0.9	0.8	0.4
14.		2.5	1.0	1.0	0.8	0.3
18.		2.8	0.9	0.9	0.8	0.5
		2.7	1.0	0.9	0.8	0.4
2.	Inter.Speed 50% Load	2.8	1.0	1.0	0.8	0.4
9.		2.3	1.0	0.8	0.6	0.1
11.		2.8	1.0	1.0	0.6	0.5
		2.6	1.0	0.9	0.7	0.3
5.	Inter.Speed 100% Load	3.3	1.0	1.0	1.0	0.5
16.		3.0	1.0	1.0	0.9	0.8
21.		3.1	1.0	1.0	0.8	0.8
		3.1	1.0	1.0	0.9	0.7
3.	High Speed 2% Load	3.3	1.0	1.0	0.9	0.5
12.		2.9	1.0	0.9	0.9	0.5
20.		3.5	1.1	0.9	1.0	0.5
		3.2	1.0	1.0	0.9	0.5
8.	High Speed 50% Load	2.8	1.0	1.0	0.8	0.5
15.		2.8	0.9	0.9	0.9	0.4
17.		2.8	0.9	0.9	0.9	0.3
		2.8	0.9	0.9	0.9	0.4
1.	High Speed 100% Load	3.3	1.0	1.0	0.8	0.9
7.		3.1	1.0	1.0	0.8	0.6
10.		3.3	1.0	1.0	0.9	0.6
		3.2	1.0	1.0	0.8	0.7
4.	Idle	2.9	1.0	0.9	0.9	0.4
13.		2.8	1.0	1.0	0.5	0.6
19.		3.1	1.1	1.0	0.9	0.6
		2.9	1.0	1.0	0.8	0.5
23.	Idle-Accel.	2.8	1.0	0.9	0.6	0.6
26.		2.5	1.0	0.9	0.5	0.3
29.		2.8	1.0	0.9	0.9	0.6
33.		3.4	1.1	1.0	0.6	0.9
		2.9	1.0	0.9	0.7	0.6
22.	Acceleration	2.8	1.0	0.9	0.8	0.6
24.		2.6	1.0	0.8	0.9	0.4
30.		4.0	1.0	1.0	0.9	1.0
32.		3.3	1.0	1.0	0.9	0.6
		3.2	1.0	0.9	0.9	0.7
25.	Deceleration	1.9	1.0	0.8	0.5	0.4
27.		2.8	1.0	1.0	0.6	0.5
28.		2.6	1.0	0.9	0.6	0.5
31.		2.9	1.0	1.0	0.8	0.4
		2.6	1.0	0.9	0.6	0.5
	Cold Start	4.6	1.6	1.0	1.0	1.0

TABLE C-40. ODOR EVALUATION SUMMARY

Engine: Mack ETAY(B)673A

Date: February 3, 1977

Run No.	Operating Condition	"D" Composite	"B" Burnt	"O" Oily	"A" Aromatic	"P" Pungent
1.	Inter.Speed	2.6	1.0	0.9	0.6	0.4
14.	2% Load	3.3	1.1	1.0	0.8	0.5
19.		3.0	1.0	0.9	0.9	0.5
		3.0	1.0	0.9	0.8	0.5
4.	Inter.Speed	2.1	1.0	0.8	0.8	0.3
7.	50% Load	3.0	1.0	1.0	0.8	0.6
11.		2.3	1.0	0.9	0.6	0.4
		2.5	1.0	0.9	0.7	0.4
10.	Inter.Speed	3.5	1.0	1.1	1.0	0.8
16.	100% Load	3.5	1.0	1.0	1.0	0.8
21.		2.9	1.0	0.9	0.9	0.3
		3.3	1.0	1.0	1.0	0.6
8.	High Speed	3.0	1.0	1.0	0.6	0.5
12.	2% Load	2.9	1.0	1.0	0.8	0.4
17.		3.3	1.0	0.9	0.9	0.8
		3.1	1.0	1.0	0.8	0.6
3.	High Speed	2.5	1.0	1.0	0.8	0.3
15.	50% Load	3.4	1.0	1.0	0.9	0.8
20.		2.8	1.0	1.0	0.8	0.5
		2.9	1.0	1.0	0.8	0.5
2.	High Speed	3.0	1.0	1.0	0.8	0.8
5.	100% Load	3.0	1.0	1.0	0.8	0.6
6.		4.3	1.4	1.0	0.9	1.0
		3.4	1.1	1.0	0.8	0.8
9.	Idle	3.1	1.0	0.9	0.9	0.5
13.		3.8	1.0	1.0	0.9	0.9
18.		3.9	1.1	1.0	1.0	0.9
		3.6	1.0	1.0	0.9	0.8
23.	Idle-Accel	2.9	1.0	0.9	0.6	0.5
26.		3.4	1.0	1.0	0.8	0.9
30.		3.5	1.0	1.0	0.9	1.0
32.		3.1	1.0	1.0	0.6	0.8
		3.2	1.0	1.0	0.7	0.8
25.	Acceleration	3.0	1.0	1.0	0.6	0.6
27.		3.0	1.0	1.0	0.6	0.4
29.		3.1	1.0	1.0	0.6	0.8
33.		3.1	1.0	1.0	0.8	0.5
		3.1	1.0	1.0	0.7	0.6
22.	Deceleration	2.8	1.1	1.0	0.6	0.4
24.		2.3	1.0	1.0	0.4	0.4
28.		3.6	1.0	1.0	0.9	0.8
31.		2.5	1.0	1.0	0.4	0.4
		2.8	1.0	1.0	0.6	0.5
	Cold Start	4.1	1.3	1.0	1.0	0.9

TABLE C-41. COMPARISON OF ODOR PANEL RATINGS - CATERPILLAR 3208 EGR

Operating Condition	Date	"D" Composite	"B" Burnt	"O" Oily	"A" Aromatic	"P" Pungent
Inter. Speed 2% Load	8/1/77	3.2	1.1	1.0	0.5	0.4
	8/3/77	3.2	1.1	0.8	0.6	0.5
	8/5/77	2.8	1.0	0.8	0.6	0.3
	Average	3.1	1.1	0.9	0.6	0.4
Inter. Speed 50% Load	8/1/77	3.2	1.1	0.9	0.7	0.4
	8/3/77	3.9	1.3	1.0	0.8	0.6
	8/5/77	3.6	1.2	0.9	0.7	0.6
	Average	3.6	1.2	0.9	0.7	0.5
Inter. Speed 100% Load	8/1/77	3.1	1.1	1.0	0.7	0.3
	8/3/77	3.6	1.1	1.0	0.6	0.7
	8/5/77	2.9	1.0	0.9	0.5	0.3
	Average	3.2	1.1	1.0	0.6	0.4
High Speed 2% Load	8/1/77	5.0	1.7	1.2	0.9	1.1
	8/3/77	4.4	1.6	1.1	0.7	0.8
	8/5/77	4.5	1.5	1.0	0.7	0.9
	Average	4.6	1.6	1.1	0.8	0.9
High Speed 50% Load	8/1/77	4.1	1.3	1.0	0.8	0.9
	8/3/77	4.3	1.7	1.0	0.8	0.8
	8/5/77	4.2	1.3	1.0	0.8	0.8
	Average	4.2	1.4	1.0	0.8	0.8
High Speed 100% Load	8/1/77	3.8	1.2	1.0	0.8	0.7
	8/3/77	3.4	1.1	0.9	0.7	0.5
	8/5/77	3.3	1.1	0.9	0.6	0.5
	Average	3.5	1.1	0.9	0.7	0.6
Idle	8/1/77	3.2	1.1	0.9	0.7	0.5
	8/3/77	3.7	1.2	1.0	0.7	0.6
	8/5/77	3.5	1.2	0.9	0.6	0.6
	Average	3.5	1.2	0.9	0.7	0.6
Idle-Acceleration	8/1/77	3.6	1.1	1.1	0.7	0.6
	8/3/77	3.7	1.3	1.0	0.7	0.7
	8/5/77	3.5	1.2	0.9	0.8	0.8
	Average	3.5	1.2	1.0	0.7	0.7
Acceleration	8/1/77	3.7	1.2	1.0	0.7	0.8
	8/3/77	3.7	1.2	1.0	0.6	0.8
	8/5/77	3.7	1.2	0.9	0.7	0.7
	Average	3.7	1.2	1.0	0.7	0.8
Deceleration	8/1/77	3.7	1.2	1.0	0.8	0.5
	8/3/77	3.4	1.1	0.9	0.7	0.6
	8/5/77	2.8	1.0	0.9	0.6	0.4
	Average	3.3	1.1	0.9	0.7	0.5
Cold Start	8/1/77	4.4	1.6	1.0	0.8	0.6
	8/3/77	4.1	1.5	1.0	0.7	0.8
	8/5/77	3.9	1.1	0.9	0.7	0.6
	Average	4.1	1.4	1.0	0.7	0.7

TABLE C-42. ENGINE ODOR EVALUATION SUMMARY

Engine: Caterpillar 3208/EGR

Date: August 1, 1977

Run No.	Operating Condition	"D" Composite	"B" Burnt	"O" Oily	"A" Aromatic	"P" Pungent
5.	Inter.Speed 2% Load	3.1	1.2	1.1	0.6	0.3
12.		3.1	1.2	1.0	0.2	0.6
18.		3.3	1.0	1.0	0.8	0.3
		3.2	1.1	1.0	0.5	0.4
1.	Inter.Speed 50% Load	3.1	1.0	1.0	0.7	0.2
7.		2.6	1.0	0.7	0.7	0.3
15.		3.9	1.3	1.1	0.7	0.8
		3.2	1.1	0.9	0.7	0.4
6.	Inter Speed 100% Load	3.1	1.1	1.1	0.7	0.3
13.		3.0	1.0	1.0	0.6	0.2
20.		3.2	1.1	1.0	0.8	0.4
		3.1	1.1	1.0	0.7	0.3
8.	High Speed 2% Load	4.9	1.7	1.3	0.7	1.0
14.		5.2	1.8	1.2	0.8	1.3
21.		5.0	1.6	1.2	1.1	0.9
		5.0	1.7	1.2	0.9	1.1
2.	High Speed 50% Load	3.7	1.1	1.1	0.8	0.6
11.		4.4	1.4	0.9	0.6	1.2
19.		4.3	1.3	1.0	1.1	1.0
		4.1	1.3	1.0	0.8	0.9
4.	High Speed 100% Load	4.0	1.4	1.1	0.7	0.6
10.		3.8	1.2	1.0	0.7	0.7
17.		3.6	1.1	1.0	0.9	0.7
		3.8	1.2	1.0	0.8	0.7
3.	Idle	2.9	1.0	0.9	0.4	0.4
9.		3.6	1.2	0.9	1.0	0.3
16.		3.1	1.2	0.9	0.6	0.7
		3.2	1.1	0.9	0.7	0.5
24.	Idle-Accel	3.4	1.0	0.9	0.8	0.7
27.		3.9	1.1	1.1	0.7	0.7
29.		3.4	1.2	1.1	0.7	0.4
31.		3.6	1.2	1.1	0.7	0.4
		3.6	1.1	1.1	0.7	0.6
23.	Accel	3.7	1.2	1.0	0.7	0.8
25.		3.5	1.1	1.0	0.7	0.7
28.		3.9	1.2	1.1	0.7	0.8
32.		3.8	1.3	1.0	0.8	0.9
		3.7	1.2	1.0	0.7	0.8
22.	Decel	3.2	1.2	0.8	0.7	0.7
26.		3.9	1.2	1.2	0.8	0.2
30.		3.7	1.2	1.1	0.8	0.6
33.		3.9	1.2	1.0	0.8	0.6
		3.7	1.2	1.0	0.8	0.5
	Cold Start	4.4	1.6	1.0	0.8	0.6

TABLE C-43. ENGINE ODOR EVALUATION SUMMARY

Engine: Caterpillar 3208 **Date:** August 3, 1977

Run No.	Operating Condition	"D" Composite	"B" Burnt	"O" Oily	"A" Aromatic	"P" Pungent
1.	Inter. Speed	3.1	1.1	0.9	0.5	0.4
11.	2% Load	3.3	1.0	0.9	0.6	0.7
15.		3.2	1.2	0.7	0.8	0.3
		3.2	1.1	0.8	0.6	0.5
3.	Inter.Speed	3.5	1.2	1.1	0.6	0.5
10.	50% Load	3.8	1.4	1.0	0.9	0.5
17.		4.3	1.3	0.9	0.9	0.8
		3.9	1.3	1.0	0.8	0.6
5.	Inter.Speed	3.8	1.2	1.1	0.5	0.8
12.	100% Load	3.5	1.1	0.9	0.6	0.6
20.		3.6	1.1	0.9	0.6	0.7
		3.6	1.1	1.0	0.6	0.7
4.	High Speed	4.9	1.8	1.2	0.7	1.0
8.	2% Load	3.5	1.2	1.0	0.7	0.5
19.		4.7	1.8	1.0	0.6	1.0
		4.4	1.6	1.1	0.7	0.8
6.	High Speed	4.2	1.5	0.9	0.7	0.9
13.	50% Load	3.5	1.2	1.0	0.8	0.4
21.		5.1	1.7	1.0	0.9	1.1
		4.3	1.7	1.0	0.8	0.8
2.	High Speed	3.2	1.0	0.9	0.5	0.5
9.	100% Load	3.8	1.3	1.0	0.8	0.6
16.		3.1	1.0	0.9	0.7	0.4
		3.4	1.1	0.9	0.7	0.5
7.	Idle	3.5	1.1	1.0	0.7	0.7
14.		3.9	1.2	1.0	0.8	0.7
18.		3.8	1.3	1.0	0.7	0.5
		3.7	1.2	1.0	0.7	0.6
24.	Idle-Accel	3.4	1.3	0.9	0.6	0.4
26.		3.6	1.2	0.9	0.6	0.7
28.		4.0	1.3	1.0	0.7	0.9
32.		3.7	1.2	1.0	0.8	0.6
		3.7	1.3	1.0	0.7	0.7
22.	Acceleration	3.0	0.9	0.9	0.4	0.7
27.		4.1	1.4	0.9	0.8	0.8
30.		3.7	1.3	1.0	0.4	0.9
33.		4.0	1.3	1.0	0.7	0.8
		3.7	1.2	1.0	0.6	0.8
23.	Deceleration	3.1	1.0	0.9	0.7	0.4
25.		3.4	1.0	0.9	0.6	0.8
27.		4.1	1.4	0.9	0.8	0.8
31.		3.1	1.0	0.9	0.8	0.4
		3.4	1.1	0.9	0.7	0.6
	Cold Start	4.1	1.5	1.0	0.7	0.8

TABEL C-44. ENGINE ODOR EVALUATION SUMMARY

Engine: Caterpillar 3208

Date August 5, 1977

Run No.	Operating Condition	"D" Composite	"B" Burnt	"O" Oily	"A" Aromatic	"P" Pungent
4.	Inter.Speed 2% Load	2.8	1.0	0.9	0.5	0.3
11.		3.0	1.1	0.8	0.7	0.4
19.		2.7	1.0	0.8	0.6	0.3
		2.8	1.0	0.8	0.6	0.3
1.	Inter.Speed 50% Load	3.5	1.0	1.0	0.9	0.4
12.		3.8	1.3	1.0	0.5	0.9
17.		3.4	1.2	0.8	0.7	0.5
		3.6	1.2	0.9	0.7	0.6
3.	Inter.Speed 100% Load	3.2	1.1	1.0	0.6	0.4
7.		2.8	1.0	0.9	0.3	0.3
13.		2.6	1.0	0.9	0.5	0.2
		2.9	1.0	0.9	0.5	0.3
2.	High Speed 2% Load	4.3	1.4	1.0	0.6	1.0
8.		4.2	1.3	0.9	0.8	0.8
15.		5.1	1.8	1.1	0.7	1.0
		4.5	1.5	1.0	0.7	0.9
6.	High Speed 50% Load	4.0	1.4	0.8	0.8	0.7
14.		4.3	1.4	1.1	0.6	0.8
21.		4.2	1.2	1.0	0.9	0.9
		4.2	1.3	1.0	0.8	0.8
5.	High Speed 100% Load	3.5	1.1	1.0	0.6	0.8
10.		2.8	1.1	0.8	0.6	0.2
18.		3.5	1.1	1.0	0.7	0.6
		3.3	1.1	0.9	0.6	0.5
9.	Idle	3.7	1.3	0.9	0.5	0.8
16.		3.3	1.1	0.9	0.5	0.5
20.		3.6	1.3	0.8	0.7	0.6
		3.5	1.2	0.9	0.6	0.6
22.	Idle-Accel	3.9	1.2	0.9	0.7	0.8
27.		3.6	1.3	0.9	0.8	0.7
29.		3.2	1.0	0.9	0.7	0.7
31.		3.4	1.1	0.9	0.8	0.8
		3.5	1.2	0.9	0.8	0.8
24.	Acceleration	4.0	1.3	0.9	0.7	0.7
26.		3.9	1.2	0.9	0.6	1.0
28.		3.2	1.0	0.9	0.9	0.4
32.		3.6	1.2	0.8	0.7	0.7
		3.7	1.2	0.9	0.7	0.7
23.	Deceleration	3.0	1.0	1.0	0.7	0.3
25.		2.7	1.1	0.8	0.4	0.3
30.		2.5	0.9	0.9	0.4	0.4
33.		2.8	0.9	0.9	0.7	0.6
		2.8	1.0	0.9	0.6	0.4
	Cold Start	3.9	1.1	0.9	0.7	0.6

TABLE C-45. COMPARISON OF GASEOUS EMISSIONS, MACK ETAY(B)673A

Operating Condition	Date	HC, ppm	CO, ppm	CO_2 %	NDIR NO, ppm	C.L. NO, ppm	C.L. NO_x, ppm	LCA, µg/ℓ	LCO, µg/ℓ	TIA
Inter. Speed 2% Load	2/1/77	209	217	1.9	223	177	210	13.0	6.3	1.8
	2/3/77	235	235	2.2	203	162	202	15.9	7.6	1.9
	Average	222	226	2.1	213	170	206	14.5	7.0	1.9
Inter. Speed 50% Load	2/1/77	123	207	6.3	945	862	887	11.9	5.3	1.7
	2/3/77	129	193	7.6	899	823	843	9.7	4.8	1.7
	Average	126	200	7.0	922	843	865	10.8	5.1	1.7
Inter. Speed 100% Load	2/1/77	62	363	8.8	1215	1087	1104	6.4	4.7	1.7
	2/3/77	59	382	9.1	1193	1062	1076	7.1	5.2	1.7
	Average	61	373	9.0	1204	1075	1090	6.8	5.0	1.7
High Speed 2% Load	2/1/77	268	235	2.4	160	127	157	17.5	6.6	1.8
	2/3/77	267	217	2.5	149	130	151	17.2	6.4	1.8
	Average	268	226	2.5	155	129	154	17.4	6.5	1.8
High Speed 50% Load	2/1/77	141	132	5.6	573	488	503	13.4	6.2	1.8
	2/3/77	169	146	6.1	528	453	473	17.8	7.4	1.9
	Average	155	139	5.9	551	471	488	15.6	6.8	1.9
High Speed 100% Load	2/1/77	41	282	8.3	924	835	848	6.4	4.7	1.7
	2/3/77	40	306	9.1	914	803	813	5.2	3.8	1.6
	Average	41	294	8.7	919	819	831	5.8	4.3	1.7
Idle	2/1/77	212	231	1.3	255	208	253	11.1	5.7	1.8
	2/3/77	229	231	1.4	239	190	242	11.9	6.1	1.8
	Average	221	231	1.4	247	199	248	11.5	5.9	1.8

TABLE C-46. GASEOUS EMISSIONS SUMMARY

ENGINE: MACK ETAY(B)673A DATE: FEBRUARY 1, 1977

					NDIR	C.L.		DOAS Results		
Operating Condition	Run No.	HC, ppm	CO, ppm	CO_2, %	NO, ppm	NO, ppm	NO_x, ppm	LCA, µg/ℓ	LCO, µg/ℓ	TIA
Inter. Speed 2% Load	6	180	212	2.0	239	190	220	12.3	6.0	1.8
	14	236	226	1.9	215	165	205	13.6	6.6	1.8
	18	212	212	1.9	215	175	205	13.2	6.2	1.8
		209	217	1.9	223	177	210	13.0	6.3	1.8
Inter. Speed 50% Load	2	132	183	6.4	976	887	925	12.1	4.5	1.7
	9	120	226	6.2	914	820	840	10.1	6.0	1.8
	11	116	212	----	945	880	895	13.6	5.3	1.7
		123	207	6.3	945	862	887	11.9	5.3	1.7
Inter. Speed 100% Load	5	62	368	9.1	1221	1087	1112	7.4	5.5	1.8
	16	44	354	8.9	1221	1100	1125	4.8	3.8	1.6
	21	80	368	8.3	1204	1075	1075	7.0	4.8	1.7
		62	363	8.8	1215	1087	1104	6.4	4.7	1.7
High Speed 2% Load	3	264	226	2.4	156	125	155	18.3	7.3	1.9
	12	262	226	2.5	168	130	157	20.4	8.4	1.9
	20	278	254	2.4	156	125	160	13.9	4.2	1.6
		268	235	2.4	160	127	157	17.5	6.6	1.8
High Speed 50% Load	8	126	155	5.6	555	480	495	11.0	5.6	1.8
	15	182	113	5.7	555	465	490	18.3	7.7	1.9
	17	116	127	5.4	610	520	525	10.9	5.2	1.7
		141	132	5.6	573	488	503	13.4	6.2	1.8
High Speed 100% Load	1	48	268	8.3	945	850	875	9.2	5.4	1.7
	7	44	283	8.3	929	830	835	4.6	4.6	1.7
	10	32	296	8.2	899	825	835	5.5	4.2	1.6
		41	282	8.3	924	835	848	6.4	4.7	1.7
Idle	4	218	226	1.3	251	210	260	11.0	4.9	1.7
	13	212	226	1.4	263	215	255	10.3	5.8	1.8
	19	206	240	1.2	251	198	245	12.0	6.5	1.8
		212	231	1.3	255	208	253	11.1	5.7	1.8

TABLE C-47. GASEOUS EMISSIONS SUMMARY

ENGINE: MACK ETAY(B)673B DATE: FEBRUARY 3, 1977

					NDIR	C.L.		DOAS Results		
Operating Condition	Run No.	HC, ppm	CO, ppm	CO_2, %	NO, ppm	NO, ppm	NO_x, ppm	LCA, µg/ℓ	LCO, µg/ℓ	TIA
Inter. Speed 2% Load	1	224	240	2.1	203	165	200	11.9	4.6	1.7
	14	246	226	2.4	215	160	200	18.6	9.4	2.0
	19	236	240	2.0	191	160	205	17.3	8.8	1.9
		235	235	2.2	203	162	202	15.9	7.6	1.9
Inter. Speed 50% Load	4	128	226	7.8	884	795	815	10.8	5.0	1.7
	7	122	183	8.0	884	840	870	8.3	3.5	1.5
	11	138	169	7.0	929	835	845	10.0	5.8	1.8
		129	193	7.6	899	823	843	9.7	4.8	1.7
Inter. Speed 100% Load	10	80	368	9.2	1170	1037	1037	11.6	8.0	1.9
	16	52	397	9.1	1187	1075	1090	4.4	3.7	1.6
	21	46	382	9.0	1221	1075	1100	5.2	3.8	1.6
		59	382	9.1	1193	1062	1076	7.1	5.2	1.7
High Speed 2% Load	8	254	212	2.4	156	135	155	21.7	9.0	2.0
	12	272	226	2.8	156	125	149	16.8	7.5	1.9
	17	276	212	2.4	134	130	150	13.1	2.6	1.4
		267	217	2.5	149	130	151	17.2	6.4	1.8
High Speed 50% Load	3	134	169	5.4	528	460	480	10.5	4.9	1.7
	15	204	127	7.0	528	445	460	26.6	11.2	2.1
	20	170	141	5.9	528	455	480	16.3	6.2	1.8
		169	146	6.1	528	453	473	17.8	7.4	1.9
High Speed 100% Load	2	48	283	8.3	929	795	805	7.9	4.7	1.7
	5	36	311	9.4	899	810	815	3.9	3.2	1.5
	6	36	325	9.7	914	805	820	3.7	3.6	1.6
		40	306	9.1	914	803	813	5.2	3.8	1.6
Idle	9	240	226	1.4	239	190	245	13.0	5.3	1.7
	13	218	226	1.6	251	190	240	11.2	6.4	1.8
	18	228	240	1.3	227	190	240	11.5	6.5	1.8
		229	231	1.4	239	190	242	11.9	6.1	1.8

TABLE C-48. COMPARISON OF GASEOUS EMISSIONS, CATERPILLAR 3208 EGR

						C.L.				
Operating Condition	Date	HC, ppm	CO, ppm	CO_2 %	NDIR NO, ppm	NO, ppm	NO_x, ppm	LCA, μg/ℓ	LCO, μg/ℓ	TIA
Inter. Apeed 2% Load	8/1/77	411	446	3.2	144	158	170			
	8/3/77	404	432	3.0	155	142	157	59.7	25.4	2.4
	8/5/77	376	423	3.2	213	175	180	32.8	17.9	2.2
	Average	397	434	3.1	171	158	169	46.3	21.7	2.3
Inter. Speed 50% Load	8/1/77	405	564	10.4	215	267	269			
	8/3/77	324	549	10.2	281	253	260	55.6	23.0	2.4
	8/5/77	404	554	10.6	262	233	238	61.7	25.2	2.4
	Average	378	556	10.4	253	251	256	58.7	24.1	2.4
Inter. Speed 100% Load	8/1/77	123	1224	12.0	1185	1191	1216			
	8/3/77	111	1140	11.2	1219	1133	1146	30.7	22.9	2.4
	8/5/77	88	1328	12.0	1357	1229	1246	20.9	13.5	2.1
	Average	107	1231	11.7	1254	1184	1203	25.8	18.2	2.3
High Speed 2% Load	8/1/77	575	826	5.5	123	143	147			
	8/3/77	575	952	5.6	147	149	151	64.4	36.2	2.5
	8/5/77	511	840	5.7	202	162	168	55.5	35.7	2.6
	Average	554	873	5.6	157	151	155	60.0	36.0	2.6
High Speed 50% Load	8/1/77	515	3038	11.6	154	177	185			
	8/3/77	412	4156	11.9	201	183	186	51.7	39.9	2.6
	8/5/77	437	5004	12.3	211	183	187	32.4	24.1	2.3
	Average	455	4066	11.9	189	181	186	42.1	32.0	2.5
High Speed 100% Load	8/1/77	25	1173	11.9	680	677	690			
	8/3/77	28	1155	11.9	722	692	694	33.8	18.7	2.3
	8/5/77	37	1178	11.8	753	703	710	16.8	11.5	2.1
	Average	30	1169	11.9	718	691	698	25.3	15.1	2.2
Idle	8/1/77	399	368	2.2	158	157	190			
	8/3/77	305	318	2.1	184	172	190	24.9	12.4	2.1
	8/5/77	369	391	2.2	209	178	189	28.6	15.3	2.2
	Average	358	359	2.2	184	169	190	26.8	13.9	2.2

TABLE C-49. GASEOUS EMISSIONS SUMMARY

Engine: Caterpillar 3208 Date: August 1, 1977

Operating Condition	Run No.	HC, ppm	CO, ppm	CO_2, %	NDIR NO ppm	C.L. NO ppm	C.L. NO_x ppm
Inter.Speed 2% Load	5	424	474	3.2	182	165	175
	12	408	391	3.2	99	150	160
	18	400	474	3.2	151	160	175
		411	446	3.2	144	158	170
Inter Speed 50% Load	1	428	391	9.8	226	230	230
	7	376	756	11.1	226	325	333
	15	412	544	10.4	193	245	245
		405	564	10.4	215	267	269
Inter Speed 100% Load	6	144	1283	11.8	1185	1162	1175
	13	124	1105	11.9	1132	1175	1187
	20	100	1283	12.2	1239	1237	1287
		123	1224	12.0	1185	1191	1216
High Speed 2% Load	8	588	812	5.6	130	130	140
	14	592	854	5.4	99	138	142
	21	544	812	5.5	140	160	160
		575	826	5.5	123	143	147
High Speed 50% Load	2	576	2668	11.1	172	180	190
	11	482	2886	11.8	140	175	180
	19	488	3559	11.8	151	175	185
		515	3038	11.6	154	177	185
High Speed 100% Load	4	28	1214	11.9	732	680	700
	10	28	1160	11.9	661	675	680
	17	20	1146	12.0	647	675	690
		25	1173	11.9	680	677	690
Idle	3	412	363	2.2	172	160	200
	9	404	377	2.3	151	150	175
	16	380	363	2.2	151	160	195
		399	368	2.2	158	157	190

TABLE C-50. GASEOUS EMISSIONS SUMMARY

ENGINE: CATERPILLAR 3208 DATE: AUGUST 3, 1977

					NDIR	L.C.		DOAS Results		
Operating Condition	Run No.	HC, ppm	CO, ppm	CO_2, %	NO, ppm	NO, ppm	NO_x, ppm	LCA, µg/ℓ	LCO, µg/ℓ	TIA
Inter. Speed 2% Load	1	432	488	3.3	145	140	160	108.0	36.1	2.6
	11	380	418	2.9	200	150	170	34.9	20.0	2.3
	15	400	391	2.9	121	135	140	36.3	20.2	2.3
		404	432	3.0	155	142	157	59.7	25.4	2.4
Inter. Speed 50% Load	3	332	572	10.6	283	260	265	48.4	18.9	2.3
	10	324	488	10.0	305	253	260	47.6	18.2	2.3
	17	316	586	10.0	255	245	255	70.9	32.0	2.5
		324	549	10.2	281	253	260	55.6	23.0	2.4
Inter. Speed 100% Load	5	108	1350	12.1	1282	1250	1250	28.9	19.2	2.3
	12	96	1077	11.7	1383	1200	1212	35.0	24.9	2.4
	20	128	994	9.8	992	950	975	28.1	24.6	2.4
		111	1140	11.2	1219	1133	1146	30.7	22.9	2.4
High Speed 2% Load	4	548	1036	5.7	186	160	160	61.6	34.2	2.5
	8	576	924	5.5	141	138	142	66.9	35.1	2.5
	19	600	896	5.5	115	150	150	64.8	39.2	2.6
		575	952	5.6	147	149	151	64.4	36.2	2.5
High Speed 50% Load	6	432	3978	11.8	186	173	175	36.6	28.9	2.5
	13	372	4263	12.3	241	195	200	78.2	55.0	2.8
	21	432	4227	11.5	176	180	183	40.4	35.9	2.6
		412	4156	11.9	201	183	186	51.7	39.9	2.6
High Speed 100% Load	2	32	1146	11.9	736	705	712	60.6	27.7	2.5
	9	24	1105	11.9	744	665	665	22.5	14.2	2.2
	16	28	1214	11.8	687	705	705	18.4	14.2	2.2
		28	1155	11.9	722	692	694	33.8	18.7	2.3
Idle	7	340	336	2.2	193	190	210	31.7	16.2	2.2
	14	272	309	2.2	248	190	210	22.2	11.8	2.1
	18	304	309	1.8	111	135	150	20.7	9.2	2.0
		305	318	2.1	184	172	190	24.9	12.4	2.1

TABLE C-51. GASEOUS EMISSIONS SUMMARY

ENGINE: CATERPILLAR 3208 DATE: AUGUST 5, 1977

					NDIR	L.C.		DOAS Results		
Operating Condition	Run No.	HC, ppm	CO, ppm	CO_2, %	NO, ppm	NO, ppm	NO_x, ppm	LCA, µg/ℓ	LCO, µg/ℓ	TIA
Inter. Speed 2% Load	4	396	418	3.2	213	175	180	31.2	15.6	2.2
	11	368	460	3.3	200	170	175	32.3	17.5	2.2
	19	364	391	3.2	227	180	185	35.0	20.5	2.3
		376	423	3.2	213	175	180	32.8	17.9	2.2
Inter. Speed 50% Load	1	368	405	10.3	276	255	260	62.3	23.6	2.4
	12	412	699	10.9	255	225	225	66.0	27.4	2.4
	17	432	558	10.6	255	220	228	56.7	24.5	2.4
		404	554	10.6	262	233	238	61.7	25.2	2.4
Inter. Speed 100% Load	3	108	1255	11.8	1331	1212	1225	20.9	15.4	2.2
	7	64	1445	12.1	1357	1237	1250	10.3	8.3	1.9
	13	92	1283	12.1	1383	1237	1262	31.4	16.8	2.2
		88	1328	12.0	1357	1229	1246	20.9	13.5	2.1
High Speed 2% Load	2	592	812	5.6	186	160	165	71.6	38.5	2.6
	8	472	840	5.7	206	160	170	41.7	29.6	2.5
	15	468	868	5.8	213	165	170	53.1	39.0	2.6
		511	840	5.7	202	162	168	55.5	35.7	2.6
High Speed 50% Load	6	392	4627	12.2	213	190	195	16.9	14.3	2.2
	14	392	4554	12.3	213	185	190	22.3	15.9	2.2
	21	528	5832	12.4	206	175	175	58.1	42.1	2.6
		437	5004	12.3	211	183	187	32.4	24.1	2.3
High Speed 100% Load	5	40	1228	11.8	753	710	715	14.9	11.4	2.1
	10	40	1187	11.8	753	690	695	8.2	7.2	1.9
	18	32	1118	11.9	753	710	720	27.3	15.8	2.2
		37	1178	11.8	753	703	710	16.8	11.5	2.1
Idle	9	360	391	2.2	200	180	195	29.8	15.8	2.2
	16	376	391	2.2	213	180	193	33.4	16.8	2.2
	20	372	391	2.2	213	173	180	22.5	13.2	2.1
		369	391	2.2	209	178	189	28.6	15.3	2.2

TABLE C-53. ALDEHYDES BY DNPH FOR CATERPILLAR 3208 EGR ENGINE

		1680 rpm			2800 rpm			
		Load %			Load %			
Aldehyde	Rate	2	50	100	2	50	100	Idle
Form Aldehyde	μg/m^3	3888	---	909	10954	28215	5	3858
	mg/hr	1569	---	545	6510	15470	8	525
	mg/kg fuel	303	---	21	510	640	0	526
	mg/kw-hr	751	---	5	2340	210	0	---
Acetane Aldehyde	μg/m^3	672	---	66	2637	5443	---	1112
	mg/hr	588	---	82	3380	6450	---	327
	mg/kg fuel	114	---	3	260	270	---	327
	mg/kw-hr	281	---	1	1220	90	---	---
Acetane	μg/m^3	327	42	16	1587	1095	33	459
	mg/hr	492	60	32	3500	2230	113	233
	mg/kg fuel	95	4	1	270	90	3	233
	mg/kw-hr	236	1	0	1260	30	1	---
Iso-butonal	μg/m^3	---	---	---	441	97	---	---
	mg/hr	---	---	---	1510	306	---	---
	mg/kg fuel	---	---	---	120	13	---	---
	mg/kw-hr	---	---	---	540	4	---	---
Crotonal	μg/m^3	411	68	509	1198	942	67	663
	mg/hr	909	137	1662	3890	2830	330	493
	mg/kg fuel	176	10	64	300	120	9	494
	mg/kw-hr	435	2	14	1400	40	2	---
Hexanol	μg/m^3	---	86	168	367	194	245	150
	mg/hr	---	357	1131	2430	1190	2440	228
	mg/kg fuel	---	25	44	190	50	70	227
	mg/kw-hr	---	6	10	870	20	20	---
Benz Adlehye	μm/m^3	---	664	1323	737	3039	738	854
	mg/hr	---	3077	9870	5460	20760	8230	1449
	mg/kg fuel	---	213	380	430	860	220	1452
	mg/kw-hr	---	53	80	1960	280	50	---

TABLE C-52. ALDEHYDES BY DNPH FOR MACK ETAY(B)673A ENGINE

		1450 rpm			1900 rpm			
		Load %			Load %			
Aldehyde	Rate	2	50	100	2	50	100	Idle
Form Aldehyde	$\mu g/m^3$	2425	1896	1403	1858	1626	1310	1877
	mg/hr	1497	1664	1980	1538	2106	2343	470
	mg/kg fuel	282	69	40	174	70	41	247
	mg/kw-hr	333	15	9	314	17	10	---
Acetane Aldehyde	$\mu g/m^3$	---	---	---	38	265	---	145
	mg/hr	---	---	---	474	106	---	78
	mg/kg fuel	---	---	---	54	4	---	41
	mg/kw-hr	---	---	---	97	1	---	---
Acetane	$\mu g/m^3$	---	---	---	---	---	---	---
	mg/hr	---	---	---	---	---	---	---
	mg/kg fuel	---	---	---	---	---	---	---
	mg/kw-hr	---	---	---	---	---	---	---
Iso-butonal	$\mu g/m^3$	489	497	516	1020	520	450	559
	mg/hr	1734	2505	4184	4855	3870	4627	804
	mg/kg fuel	327	104	84	549	129	81	422
	mg/kw-hr	385	22	19	991	32	19	---
Crotonal	$\mu g/m^3$	337	---	321	492	369	254	631
	mg/hr	1137	---	2478	2226	2611	2482	863
	mg/kg fuel	214	---	50	252	87	43	453
	mg/kw-hr	253	---	11	454	21	10	---
Hexanol	$\mu g/m^3$	---	---	395	89	53	409	72
	mg/hr	---	---	6205	821	762	8144	202
	mg/kg fuel	---	---	124	93	25	142	106
	mg/kw-hr	---	---	27	167	6	33	---
Benz Aldehyde	$\mu g/m^3$	---	---	---	---	---	---	---
	mg/hr	---	---	---	---	---	---	---
	mg/kg fuel	---	---	---	---	---	---	---
	mg/kw-hr	---	---	---	---	---	---	---

TABLE C-54. ALDEHYDES BY DNPH FOR CHEVROLET 366 ENGINE

		1200 rpm				2300 rpm				
		% Load				% Load				
Aldehyde	Rate	2	50	100	CT	2	50	100	CT	Idle
Form-aldehyde	µg/m^3	1888	545	40861		-----	-----	15999		21396
	mg/hr	211	99	11417	3661	-----	-----	9195	4956	1400
	mg/kg fuel	47	12	705	1345	-----	-----	266	1041	551
	mg/kw-hr	171	5	264	-----	-----	-----	105	----	0
Acet-aldehyde	µg/m^3	156	----	2191		-----	-----	1348		4170
	mg/hr	38	----	1325	1974	-----	-----	1676	2357	590
	mg/kg fuel	9	----	82	725	-----	-----	49	495	232
	mg/kw-hr	31	----	31	0	-----	-----	19	0	0
Acetone	µg/m^3	481	471	481		26	-----	988		1756
	mg/hr	199	243	502	938	248	-----	2106	995	427
	mg/kg fuel	45	28	31	345	33	-----	61	209	168
	mg/kw-hr	161	11	12	0	128	-----	24	0	0
Iso-butanal	µg/m^3	198	239	101		30	1	473		835
	mg/hr	127	249	162	412	358	0	1563	499	314
	mg/kg fuel	29	29	10	151	48	0	45	105	123
	mg/kw-hr	103	11	4	0	185	0	18	0	0
Crotonal	µg/m^3	5620	5876	992		411	589	3268		170424
	mg/hr	3431	5790	1514	1927	4767	1095	10266	2192	60927
	mg/kg fuel	772	672	94	708	637	63	297	460	23986
	mg/kw-hr	2789	265	35	0	2471	25	117	0	0
Hexanal	µg/m^3	418	1845	235		56	75	228		465
	mg/hr	519	3708	727	1651	930	284	1460	1591	338
	mg/kg fuel	117	430	45	607	124	16	42	334	133
	mg/kw-hr	422	170	17	0	482	6	17	0	0
Benz-aldehyde	µg/m^3	3002	4629	11881		234	449	5319		8262
	mg/hr	4180	10401	41357	18248	4102	1892	38091	25687	6734
	mg/kg fuel	940	1207	2554	6705	548	108	1102	5393	2651
	mg/kw-hr	3397	477	955	0	2126	42	434	0	0

TABLE C-55. SPECIFIC HYDROCARBON EMISSION RATES, MACK ETAY(B)673A

		1450 rpm			1900 rpm			
		% Load			% Load			
Hydrocarbon	Rate	2	50	100	2	50	100	Idle
Methane	$\mu g/m^3$	2198	733	400	2131	733	400	2331
CH_4	mg/hr	1001	481	403	1280	692	524	425
	mg/kg fuel	186	20	8	143	23	9	223
	mg/kw-hr	223	4	2	261	6	2	----
Ethylene	$\mu g/m^3$	6292	6525	5418	7050	5418	6467	7224
C_2H_4	mg/hr	2866	4280	5463	4234	5114	8472	1316
	mg/kg fuel	531	174	109	474	170	148	691
	mg/kw-hr	637	38	24	864	42	35	----
Ethane	$\mu g/m^3$	125	312	----	125	62	----	187
C_2H_6	mg/hr	57	205	----	75	59	----	34
	mg/kg fuel	11	8	----	8	2	----	18
	mg/kw-hr	13	2	----	15	1	----	----
Acetylene	$\mu g/m^3$	325	217	541	487	162	541	433
C_2H_2	mg/hr	148	142	545	292	153	708	79
	mg/kg fuel	27	6	11	33	5	12	41
	mg/kw-hr	33	1	2	60	1	3	----
Propane	$\mu g/m^3$	----	----	----	----	----	----	----
C_3H_8	mg/hr	----	----	----	----	----	----	----
	mg/kg fuel	----	----	----	----	----	----	----
	mg/kw-hr	----	----	----	----	----	----	----
Propylene	$\mu g/m^3$	2330	3263	1806	2622	2797	2039	2505
C_3H_6	mg/hr	1061	2140	1821	1575	2639	2671	456
	mg/kg fuel	197	87	36	176	88	47	240
	mg/kw-hr	236	19	8	321	22	11	----
Benzene	$\mu g/m^3$	505	674	786	562	506	674	730
C_6H_6	mg/hr	222	426	763	325	459	850	128
	mg/kg fuel	41	17	15	36	15	15	67
	mg/kw-hr	49	4	3	66	4	4	----
Toluene	$\mu g/m^3$	----	164	----	219	110	110	219
C_7H_8	mg/hr	----	108	----	131	103	143	40
	mg/kg fuel	----	4	----	15	3	3	21
	mg/kw-hr	----	1	----	27	1	1	----

TABLE C-56. SPECIFIC HYDROCARBON EMISSION RATES, CATERPILLAR 3208/EGR

		1680 rpm			2800 rpm			
		% Load			% Load			
Hydrocarbon	Rate	2	50	100	2	50	100	Idle
Methane	µg/m^3	4129	4062	2131	7525	30434	466	4795
CH_4	mg/hr	1208	1147	925	3285	12220	311	487
	mg/kg fuel	242	80	36	262	500	8	467
	mg/kw-hr	578	20	8	1182	163	2	----
Ethylene	µg/m^3	18119	20159	24179	24470	106037	2564	17071
C_2H_4	mg/hr	5300	5692	10503	10680	42567	1712	1734
	mg/kg fuel	1062	395	409	850	1741	46	1663
	mg/hw-hr	2536	97	90	3842	566	11	----
Ethane	µg/m^3	312	499	187	562	2684	----	437
C_2H_6	mg/hr	91	141	81	245	1078	----	44
	mg/kg fuel	18	10	3	20	44	----	43
	mg/kw-hr	44	2	1	88	14	----	----
Acetylene	µg/m^3	1516	1786	2652	5413	15265	1191	1191
C_2H_2	mg/hr	443	504	1511	2360	6121	794	121
	mg/kg fuel	89	35	45	188	250	21	116
	mg/kw-hr	212	9	10	849	81	5	----
Propane	µg/m^3	----	59	----	----	115	----	115
C_3H_8	mg/hr	----	17	----	----	49	----	12
	mg/kg fuel	----	1	----	----	2	----	12
	mg/kw-hr	----	0	----	----	1	----	----
Propylene	µg/m^3	5884	10312	5011	10953	23188	350	5477
C_3H_6	mg/hr	1721	2912	2177	4781	9309	233	557
	mg/kg fuel	345	202	85	381	381	6	534
	mg/kw-hr	824	50	19	1720	124	2	----
Benzene	µg/m^3	1854	5169	4213	3371	13033	786	2753
C_6H_6	mg/hr	522	1405	1761	1416	5036	506	269
	mg/kg fuel	105	97	69	113	206	13	258
	mg/kw-hr	250	24	15	509	67	3	----
Toluene	µg/m^3	493	603	384	712	3726	----	548
C_7H_8	mg/hr	144	170	166	310	1492	----	56
	mg/kg fuel	29	12	7	25	61	----	53
	mg/kw-hr	69	3	1	112	20	----	----

TABLE C-57. SPECIFIC HYDROCARBON EMISSION RATES, CHEV 366 ENGINE

Hydrocarbon	Rate	1200 rpm				2300 rpm				
		% Load				% Load				
		2	50	100	CT	2	50	100	CT	Idle
Methane	μg/m^3	2531	13785	215368	22509	1132	799	237944	9523	21044
CH_4	mg/hr	211	1854	44875	1348	159	202	102670	1052	1027
	mg/kg fuel	47	215	2771	495	21	12	2951	221	0
	mg/kw-hr	171	85	1037	0	83	5	1171	0	404
Ethylene	μg/m^3	8623	28723	140644	141402	3729	---	125496	6898	52611
C_2H_4	mg/hr	718	3863	29299	8467	524	---	54141	7617	2566
	mg/kg fuel	162	448	1809	3111	70	---	1556	1599	1010
	mg/kw-hr	584	177	677	0	272	---	617	0	0
Ethane	μg/m^3	437	1124	11549	15232	----	---	10925	-----	5306
C_2H_6	mg/hr	36	151	2407	913	----	---	4715	-----	259
	mg/kg fuel	8	18	149	335	----	---	136	-----	102
	mg/kw-hr	30	7	56	0	----	---	54	-----	0
Acetylene	μg/m^3	2761	6929	54780	22572	1353	---	43142	5359	18621
C_2H_2	mg/hr	230	931	11399	1350	190	---	18590	591	907
	mg/kg fuel	187	43	263	0	99	---	212	0	357
	mg/kw-hr	52	108	704	496	25	---	534	124	0
Propane	μg/m^3	----	144	1903	14185	----	---	1384	3560	1499
C_3H_8	mg/hr	----	21	420	899	----	---	632	404	77
	mg/kg fuel	----	2	26	330	----	---	18	85	0
	mg/kw-hr	----	1	10	0	----	---	7	0	31
Propylene	μg/m^3	2447	6933	48008	85354	524	---	34258	39443	22081
C_3H_6	mg/hr	204	932	10001	5111	74	---	14779	4355	1077
	mg/kg fuel	46	108	618	1878	10	---	425	914	424
	mg/kw-hr	166	43	231	0	38	---	169	0	0
Benzene	μg/m^3	5281	14606	103705	289541	1629	112	92357	78481	48538
C_6H_6	mg/hr	423	1891	20793	16687	221	27	38347	8340	2279
	mg/kg fuel	95	219	1284	6131	30	2	1102	1751	897
	mg/kw-hr	344	87	480	0	114	1	437	0	0
Toluene	μg/m^3	8659	19674	191968	1379999	1206	---	104999	302063	157443
C_7H_8	mg/hr	719	2639	29881	82407	169	---	45172	33261	7659
	mg/kg fuel	162	306	2463	30279	23	---	1298	6983	3015
	mg/kw-hr	585	121	921	0	88	---	515	0	0

APPENDIX D

SULFATE AND PARTICULATE CHARACTERIZATION

Table D-1. 21 -MODE EPA EXP DIESEL EMISSION CYCLE

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CATERPILLAR 3406 DIESEL ENGINE  DIRECT INJECTION  28 DEG.BTDC  W/O EGR
TEST 1  RUN 1  FUEL: EM-272-F  PROJECT: 11-4623-001  TEST DATE 11-9-77
------------------------------------------------------------------  . -----------------------------------------------------------------------------
MODE  ENGINE  TORQUE  POWER   FUEL     AIR    EXHAUST   FUEL          MODE   HC      CO+     NO++  WEIGHTED  BSHC      BSCO+     BSNO2++   HUM.
      SPEED                   FLOW     FLOW    FLOW      AIR                                                                                MILLI
       RPM    N X M     KW   KG/MIN   KG/MIN  KG/MIN    RATIO                PPM     PPM     PPM      KW     G/KW HR   G/KW HR   G/KW HR    G/KG
------------------------------------------------------------------  . -----------------------------------------------------------------------------
  1    700      0.0    0.0    .030     5.47     5.50    .006            1     222     749     159     0.00        K         K         R      3.7
  2   1260     30.9    4.1    .077     4.91     9.99    .008            2     236     587     230      .30    16.85     83.52     53.81      3.7
  3   1260    118.7   15.7    .111     9.88     9.99    .011            3     184     479     412     1.14     3.42     17.72     25.06      3.7
  4   1260    268.3   35.4    .172    10.01    10.18    .017            4     170     321     782     2.16     1.42      5.36     21.43      3.7
  5   1260    370.3   48.9    .215    10.17    10.39    .021            5     162     269     986     1.76     1.00      3.32     19.96      3.7
  6   1260    747.8   98.7    .376    11.42    11.80    .033            6     142     258    1081     7.20      .44      1.79     12.31      3.7
  7   1260   1122.9  148.1    .551    13.12    13.67    .042            7     100     522    1264     0.00        I         I         I      3.7
  8   1260   1227.3  161.9    .598    13.49    14.04    .044            8      78     618    1323     7.93      .20      3.12     10.96      3.7
  9   1260   1379.2  182.0    .671    14.29    14.96    .047            9      48     837    1369     0.00        I         I         I      3.7
 10   1260   1486.1  196.1    .733    14.95    15.69    .049           10      32     983    1375     0.00        I         I         I      3.7
 11    700      0.0    0.0    .030     5.34     5.37    .006           11     128     278     300     0.00        K         H         H      3.7
 12   2100   1132.4  249.0    .964    23.73    24.70    .041           12      54     330    1130     7.47      .16      1.40     10.68      3.7
 13   2100   1051.6  231.2    .898    22.95    23.85    .039           13      42     283    1132    15.44      .13      1.69     11.12      3.7
 14   2100    942.4  207.2    .804    21.65    22.46    .037           14      43     261    1113     8.41      .14      1.64     11.49      3.7
 15   2100    861.7  184.5    .741    20.94    21.68    .035           15      45     238    1042    13.83      .15      1.58     11.36      3.7
 16   2100    576.9  126.8    .535    18.47    19.01    .029           16      52     241     744     9.26      .23      2.09     10.62      3.7
 17   2100    289.6   63.7    .336    16.41    16.74    .021           17      68     295     528     0.00        I         I         I      3.7
 18   2100    208.9   45.9    .281    15.94    16.22    .018           18      84     296     453     3.63      .86      6.07     15.25      3.7
 19   2100     95.0   20.9    .206    15.50    15.70    .013           19     105     349     327     0.00        I         I         I      3.7
 20   2100     21.4    4.7    .163    15.37    15.54    .011           20     128     377     236     0.00        I         I         I      3.7
 21    700      0.0    0.0    .030     5.56     5.59    .005           21     127     381     190     0.00        H         R         R      3.7
                                                                      CYCLE COMPOSITE   BSHC    =   .469   GRAM/KW  HR
                                                                                        BSCO+   =  3.255   GRAM/KW  HR
                                                                                        BSNO2++=  12.592   GRAM/KW  HR
                                                                                 BSHC + BSNO2++=  13.061   GRAM/KW  HR
                                                                                        BSFC    =   .255KG/KW HR

                                                                       +  CONVERTED TO WET BASIS
                                                                       ++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS
                                                                          WATER PER KG DRY AIR
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Table D-2. 21-MODE EPA EXP DIESEL EMISSION CYCLE

CATERPILLAR 3406 DIESEL ENGINE DIRECT INJECTION 28 DEG.BTDC W/O EGR
TEST 1 RUN 2 FUEL: EM-272-F PROJECT: 11-4623-001 TEST DATE 11-4-77

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.030	5.35	5.38	.006
2	1260	30.4	4.1	.076	9.82	9.90	.008
3	1260	118.7	15.7	.079	9.92	10.00	.008
4	1260	268.3	35.4	.170	10.01	10.18	.017
5	1260	370.3	48.9	.212	10.16	10.38	.021
6	1260	750.2	99.0	.376	11.39	11.77	.033
7	1260	1120.5	147.8	.549	13.08	13.63	.042
8	1260	1224.7	162.2	.598	13.41	14.01	.045
9	1260	1376.4	181.7	.672	14.29	14.96	.047
10	1260	1488.4	196.4	.733	14.87	15.60	.049
11	700	0.0	0.0	.030	5.44	5.47	.006
12	2100	1130.0	248.5	.964	23.87	24.83	.040
13	2100	1056.4	232.3	.900	23.00	23.90	.039
14	2100	937.7	206.2	.801	21.63	22.43	.037
15	2100	857.0	188.4	.737	21.02	21.76	.035
16	2100	576.9	126.8	.536	18.38	18.92	.029
17	2100	289.6	63.7	.336	16.42	16.75	.020
18	2100	208.9	45.9	.280	15.95	16.23	.018
19	2100	90.2	19.8	.204	15.46	15.66	.013
20	2100	21.4	4.7	.163	15.33	15.50	.011
21	700	0.0	0.0	.030	5.57	5.60	.005

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	168	511	149	0.00	R	R	R	3.7
2	180	431	228	.30	12.73	60.69	52.66	3.7
3	164	302	401	1.14	3.05	11.19	24.37	3.7
4	148	147	773	2.16	1.24	2.45	21.18	3.7
5	132	97	946	1.76	.82	1.20	19.13	3.7
6	116	100	1048	7.22	.40	.69	11.87	3.7
7	92	378	1191	0.00	I	I	I	3.7
8	78	472	1270	7.95	.20	2.36	10.94	3.7
9	56	615	1328	0.00	I	I	I	3.7
10	36	808	1344	0.00	I	I	I	3.7
11	112	176	262	0.00	R	R	R	3.6
12	68	283	1130	7.95	.20	1.64	10.76	3.6
13	47	236	1142	15.56	.14	1.41	11.20	3.6
14	44	213	1113	8.87	.14	1.34	11.53	3.6
15	45	190	1054	13.76	.15	1.27	11.59	3.6
16	58	192	754	9.26	.25	1.66	10.70	3.6
17	73	220	539	0.00	I	I	I	3.6
18	80	246	465	3.63	.82	5.05	15.63	3.6
19	108	299	337	0.00	I	I	I	3.6
20	127	326	251	0.00	I	I	I	3.6
21	131	355	208	0.00	R	R	R	3.6

CYCLE COMPOSITE BSHC = .428 GRAM/KW HR
BSCO+ = 2.383 GRAM/KW HR
BSNO2++= 12.544 GRAM/KW HR
BSHC + BSNO2++= 12.972 GRAM/KW HR
BSFC = .253KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

Table D-3. 13-MODE FEDERAL DIESEL EMISSION CYCLE

CATERPILLAR 3406 DIESEL ENGINE,DIRECT INJECTION,28 DEG BTDC,W/O EGR
TEST 1 RUN 1 FUEL EM-272-F PROJECT: 11-4623-001 TEST DATE 11-9-77

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.030	5.47	5.50	.006
2	1260	30.9	4.1	.077	9.91	9.99	.008
3	1260	370.3	48.9	.215	10.17	10.39	.021
4	1260	747.8	98.7	.376	11.42	11.80	.033
5	1260	1122.9	148.1	.551	13.12	13.67	.042
6	1260	1486.1	196.1	.733	14.95	15.69	.049
7	700	0.0	0.0	.030	5.34	5.37	.006
8	2100	1132.4	249.0	.964	23.73	24.70	.041
9	2100	861.7	189.5	.741	20.94	21.68	.035
10	2100	576.9	126.8	.535	18.47	19.01	.029
11	2100	289.6	63.7	.336	16.41	16.74	.021
12	2100	21.4	4.7	.163	15.37	15.54	.011
13	700	0.0	0.0	.030	5.56	5.59	.005

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	222	749	150	0.00	R	R	R	3.7
2	236	587	213	.33	16.85	33.52	49.88	3.7
3	162	264	919	3.91	1.00	3.32	18.61	3.7
4	142	258	1027	7.89	.49	1.74	11.70	3.7
5	100	522	1250	11.85	.27	2.79	10.98	3.7
6	32	483	1426	15.68	.07	4.56	10.87	3.7
7	128	278	237	0.00	R	R	R	3.7
8	54	330	1204	19.92	.16	1.90	11.37	3.7
9	45	238	1111	15.16	.15	1.58	12.10	3.7
10	52	241	764	10.15	.23	2.09	10.41	3.7
11	68	295	552	5.05	.52	4.49	13.82	3.7
12	128	377	254	.38	12.32	72.37	79.41	3.7
13	127	381	206	0.00	R	R	R	3.7

CYCLE COMPOSITE BSHC = .417 GRAM/KW HR
BSCO+ = 3.564 GRAM/KW HR
BSNO2++= 12.437 GRAM/KW HR
BSHC + BSNO2++= 12.854 GRAM/KW HR
BSFC = .253KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

Table D-4 · 13-MODE FEDERAL DIESEL EMISSION CYCLE

CATERPILLAR 3406 DIESEL ENGINE,DIRECT INJECTION,28 DEG BTDC,W/O EGR
TEST 1 RUN 2 FUEL EM-272-F PROJECT: 11-4623-001 TEST DATE 11-9-77

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.030	5.35	5.38	.006
2	1260	30.9	4.1	.076	9.82	9.90	.008
3	1260	370.3	48.9	.212	10.16	10.38	.021
4	1260	750.2	99.0	.376	11.39	11.77	.033
5	1260	1120.5	147.8	.549	13.08	13.63	.042
6	1260	1488.4	196.4	.733	14.97	15.60	.049
7	700	0.0	0.0	.030	5.44	5.47	.006
8	2100	1130.0	248.5	.964	23.87	24.83	.040
9	2100	857.0	188.4	.737	21.02	21.76	.035
10	2100	576.9	126.8	.536	18.38	18.92	.029
11	2100	284.6	63.7	.336	16.42	16.75	.020
12	2100	21.4	4.7	.163	15.33	15.50	.011
13	700	0.0	0.0	.030	5.57	5.60	.005

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	168	511	163	0.00	*	*	*	3.7
2	180	431	254	.33	12.73	60.64	58.76	3.7
3	132	97	1042	3.91	.82	1.20	22.06	3.7
4	116	100	1241	7.92	.40	.69	14.06	3.7
5	92	376	1536	11.83	.25	2.02	13.49	3.7
6	361	808	1643	15.71	.83	3.72	12.81	3.7
7	112	176	180	0.00	*	*	*	3.6
8	68	283	1212	19.88	.20	1.64	11.53	3.6
9	45	190	1122	15.08	.15	1.27	12.34	3.6
10	58	192	802	10.15	.25	1.66	11.34	3.6
11	73	220	600	5.04	.56	3.36	15.04	3.6
12	127	326	296	.38	12.14	62.32	93.04	3.6
13	131	355	235	0.00	*	*	*	3.6

CYCLE COMPOSITE BSHC = .522 GRAM/KW HR
BSCO+ = 2.697 GRAM/KW HR
BSNO2++= 13.742 GRAM/KW HR
BSHC + BSNO2++= 14.264 GRAM/KW HR
BSFC = .253KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

Table D-5 . 13-MODE FEDERAL DIESEL EMISSION CYCLE

CATERPILLAR 3406 DIESEL ENGINE,DIRECT INJECTION,28 DEG.BTDC,W/EGR
PROJECT: 11-4623-001 FUEL EM-272-F

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.029	2.42	2.45	.012
2	1260	30.9	4.1	.074	4.21	4.29	.018
3	1260	370.3	48.9	.230	4.21	4.44	.055
4	1260	747.8	98.7	.401	8.51	8.91	.047
5	1260	1122.9	148.1	.604	11.30	11.90	.053
6	1260	1403.0	185.1	.718	13.60	14.32	.053
7	700	0.0	0.0	.029	2.42	2.45	.012
8	2100	1058.8	232.8	.947	19.87	20.82	.048
9	2100	861.7	189.5	.802	16.22	17.02	.049
10	2100	576.9	126.8	.559	13.24	13.80	.042
11	2100	287.2	63.2	.352	9.61	9.96	.037
12	2100	23.7	5.2	.163	7.07	7.23	.023
13	700	0.0	0.0	.029	2.42	2.45	.012

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/K
1	210	544	208	0.00	R	R	R	17.3
2	208	563	182	.33	6.37	34.36	18.27	17.5
3	250	809	288	3.91	.66	4.27	2.50	14.7
4	70	1426	708	7.89	.18	7.47	6.08	15.6
5	10	2861	910	11.85	.02	13.33	6.97	17.8
6	51	1618	1143	14.01	.11	7.26	8.42	15.3
7	210	544	208	0.00	R	R	R	17.3
8	16	532	1035	18.62	.04	2.76	8.81	14.0
9	20	794	847	15.16	.05	4.13	7.25	14.0
10	68	756	523	10.15	.22	4.77	5.41	14.2
11	146	399	404	5.05	.67	3.65	6.06	13.7
12	114	559	134	.42	4.60	44.91	17.68	14.6
13	210	544	208	0.00	R	R	R	17.3

CYCLE COMPOSITE BSHC = .229 GRAM/KW HR
BSCO+ = 6.434 GRAM/KW HR
BSNO2++= 7.345 GRAM/KW HR
BSHC + BSNO2++= 7.574 GRAM/KW HR
BSFC = .268KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

Table D-6 . 21 -MODE EPA EXP DIESEL EMISSION CYCLE

CATERPILLAR 3406 DIESEL ENGINE,DIRECT INJECTION,18 DEG. BTDC
TEST 1 RUN 1 FUEL EM-272-F PROJECT: 11-4623-001 TEST DATE 12-13-77

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.031	5.62	5.65	.006
2	1260	28.5	3.8	.073	4.55	9.62	.008
3	1260	113.9	15.0	.107	9.71	9.82	.011
4	1260	258.8	34.1	.168	9.79	9.96	.017
5	1260	358.5	47.3	.209	9.93	10.14	.021
6	1260	716.9	94.6	.373	11.31	11.68	.033
7	1260	1070.6	141.3	.548	12.96	13.51	.042
8	1260	1172.7	154.7	.603	13.60	14.20	.044
9	1260	1317.5	173.8	.683	14.38	15.07	.048
10	1260	1417.2	187.0	.742	14.73	15.47	.050
11	700	0.0	0.0	.026	5.19	5.22	.005
12	2100	1037.4	228.1	.999	24.44	25.44	.041
13	2100	961.4	211.4	.903	23.14	24.04	.039
14	2100	857.0	188.4	.803	21.94	22.74	.037
15	2100	781.0	171.7	.741	20.93	21.67	.035
16	2100	522.3	114.8	.525	18.27	18.79	.029
17	2100	261.1	57.4	.336	16.02	16.36	.021
18	2100	187.5	41.2	.283	15.75	16.03	.018
19	2100	83.1	18.3	.208	15.21	15.42	.014
20	2100	21.4	4.7	.166	13.12	13.28	.013
21	700	0.0	0.0	.024	5.40	5.42	.004

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	142	30	185	0.00	R	R	R	15.0
2	268	118	136	.27	19.96	17.55	33.18	15.0
3	248	117	215	1.10	4.71	4.45	13.36	15.0
4	208	120	315	2.08	1.77	2.03	8.74	15.0
5	188	171	355	1.70	1.17	2.13	7.35	15.0
6	120	118	556	6.90	.43	.84	6.54	15.0
7	64	454	727	0.00	I	I	I	15.0
8	50	477	774	7.58	.13	2.54	6.77	15.6
9	26	601	822	0.00	I	I	I	15.6
10	12	622	842	0.00	I	I	I	15.6
11	116	60	191	0.00	R	R	R	15.6
12	17	455	602	7.30	.06	2.44	6.33	15.6
13	19	435	601	14.16	.06	2.87	6.51	15.6
14	20	200	562	6.10	.07	1.40	6.46	15.6
15	23	200	536	12.54	.08	1.47	6.45	15.6
16	45	178	393	8.38	.21	1.69	6.13	15.6
17	92	174	220	0.00	I	I	I	15.2
18	120	177	186	3.26	1.36	3.99	6.91	15.2
19	166	176	153	0.00	I	I	I	15.2
20	148	176	122	0.00	I	I	I	15.2
21	132	107	185	0.00	R	R	R	15.2

CYCLE COMPOSITE BSHC = .477 GRAM/KW HR
BSCO+ = 2.279 GRAM/KW HR
BSNO2++= 7.121 GRAM/KW HR
BSHC + BSNO2++= 7.598 GRAM/KW HR
BSFC = .275KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRA
WATER PER KG DRY AIR

Table D-7. 21-MODE EPA EXP DIESEL EMISSION CYCLE

CATERPILLAR 3406 DIESEL ENGINE,DIRECT INJECTION,18 DEG. BTDC
TEST 1 RUN 2 FUEL: EM-272-F PROJECT: 11-4623-001 TEST DATE 12-15-77

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.031	5.56	5.59	.006
2	1260	28.5	3.8	.079	9.66	9.74	.008
3	1260	116.3	15.3	.112	9.87	9.98	.011
4	1260	261.1	34.5	.170	9.95	10.12	.017
5	1260	363.2	47.9	.217	10.25	10.46	.021
6	1260	724.0	95.5	.378	11.45	11.83	.033
7	1260	1087.2	143.4	.560	13.21	13.77	.042
8	1260	1187.0	156.6	.610	13.78	14.39	.044
9	1260	1331.8	175.7	.691	14.30	14.99	.048
10	1260	1431.5	188.9	.748	14.82	15.56	.051
11	700	0.0	0.0	.027	5.27	5.29	.005
12	2100	1042.1	229.2	.996	24.23	25.23	.041
13	2100	961.4	211.4	.898	23.18	24.08	.039
14	2100	857.0	188.4	.799	21.69	22.49	.037
15	2100	785.8	172.8	.738	21.16	21.90	.035
16	2100	522.3	114.8	.525	18.31	18.83	.029
17	2100	261.1	57.4	.336	16.22	16.56	.021
18	2100	187.5	41.2	.285	15.79	16.07	.018
19	2100	83.1	18.3	.215	15.39	15.60	.014
20	2100	21.4	4.7	.172	14.95	15.12	.011
21	700	0.0	0.0	.026	5.34	5.36	.005

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	171	131	177	0.00	R	R	R	12.8
2	272	223	136	.27	20.51	33.45	[illegible]	12.8
3	234	244	212	1.12	4.43	9.21	[illegible]	12.8
4	215	241	304	2.10	1.84	4.11	[illegible]	12.8
5	197	256	340	1.73	1.25	3.24	[illegible]	12.8
6	116	266	542	6.97	.42	1.91	[illegible]	12.8
7	52	558	713	0.00	I	I	I	12.8
8	36	643	752	7.67	.10	3.42	[illegible]	13.0
9	20	757	796	0.00	I	I	I	13.0
10	7	813	809	0.00	I	I	I	13.0
11	113	108	180	0.00	R	R	R	13.0
12	19	482	610	7.33	.06	3.08	6.39	13.0
13	23	443	594	14.16	.08	2.93	6.44	13.0
14	25	471	563	8.10	.04	3.26	6.40	13.0
15	30	479	511	12.61	.11	3.52	6.17	12.0
16	54	373	378	8.38	.26	3.54	[illegible]	12.0
17	104	356	207	0.00	I	I	I	12.0
18	150	342	191	3.26	1.70	7.74	[illegible]	11.8
19	190	373	145	0.00	I	I	I	11.8
20	228	364	116	0.00	I	I	I	11.1
21	163	137	168	0.00	R	R	R	11.1

CYCLE COMPOSITE BSHC = .515 GRAM/KW HR
BSCO+ = 3.713 GRAM/KW HR
BSNO2++= 6.968 GRAM/KW HR
BSHC + BSNO2++= 7.482 GRAM/KW HR
BSFC = .275KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

Table D-8. 13-MODE FEDERAL DIESEL EMISSION CYCLE

CATERPILLAR 3406 DIESEL ENGINE, DIRECT INJECTION, 18 DEG. BTDC
TEST 1 RUN 1 FUEL: EM-272-F PROJECT: 11-4623-001 TEST DATE 12-13-77

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.031	5.62	5.65	.006
2	1260	28.5	3.8	.073	9.55	9.62	.008
3	1260	358.5	47.3	.209	4.93	10.14	.021
4	1260	716.9	94.6	.373	11.31	11.68	.033
5	1260	1070.6	141.3	.548	12.96	13.51	.042
6	1260	1417.2	187.0	.742	12.76	13.50	.058
7	700	0.0	0.0	.026	5.19	5.22	.005
8	2100	1037.4	228.1	.999	24.44	25.44	.041
9	2100	781.0	171.7	.741	20.93	21.67	.035
10	2100	522.3	114.8	.525	18.27	18.79	.029
11	2100	261.1	57.4	.336	16.02	16.36	.021
12	2100	21.4	4.7	.166	13.12	13.28	.013
13	700	0.0	0.0	.023	5.40	5.42	.004

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	142	30	182	0.00	R	R	R	15.0
2	268	118	128	.30	19.46	17.55	31.32	15.0
3	188	171	350	3.78	1.17	2.13	7.14	15.0
4	120	118	569	7.57	.43	.84	6.64	15.0
5	64	454	739	11.30	.18	2.52	6.74	15.0
6	12	612	798	14.96	.03	2.56	5.49	15.6
7	116	60	213	0.00	R	R	R	15.6
8	17	455	616	18.25	.06	2.94	6.54	15.6
9	23	200	553	13.74	.08	1.47	6.65	15.8
10	45	178	424	9.19	.21	1.69	6.60	15.8
11	92	179	247	4.59	.76	2.46	6.70	15.2
12	148	176	125	.38	16.24	28.84	33.68	15.2
13	132	107	187	0.00	R	R	R	15.2

CYCLE COMPOSITE
BSHC = .404 GRAM/KW HR
BSCO+ = 2.431 GRAM/KW HR
BSNO2++= 6.904 GRAM/KW HR
BSHC + BSNO2++= 7.309 GRAM/KW HR
BSFC = .273KG/KW HR

+ CONVERTED TO WET BASIS

++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

Table D-9. 13-MODE FEDERAL DIESEL EMISSION CYCLE

CATERPILLAR 3406 DIESEL ENGINE, DIRECT INJECTION, 18 DEG. BTDC
TEST 1 RUN 2 FUEL: EM-272-F PROJECT: 11-4623-001 TEST DATE 12-15-77

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.031	5.54	5.57	.006
2	1260	28.5	3.8	.079	9.66	9.74	.008
3	1260	363.2	47.9	.217	10.25	10.46	.021
4	1260	724.0	95.5	.378	11.45	11.83	.033
5	1260	1087.2	143.4	.560	13.21	13.77	.042
6	1260	1431.5	188.9	.748	14.82	15.56	.051
7	700	0.0	0.0	.027	5.27	5.29	.005
8	2100	1042.1	229.2	.998	24.23	25.23	.041
9	2100	785.8	172.8	.738	21.16	21.90	.035
10	2100	522.3	114.8	.525	18.31	18.83	.029
11	2100	261.1	57.4	.336	16.22	16.56	.021
12	2100	21.4	4.7	.172	14.95	15.12	.011
13	700	0.0	0.0	.026	5.34	5.36	.005

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	171	131	164	0.00	R	R	R	12.8
2	272	223	122	.30	20.51	33.45	29.99	12.8
3	197	256	356	3.83	1.25	3.24	7.40	12.8
4	116	266	592	7.64	.42	1.41	6.87	12.8
5	52	558	743	11.48	.15	3.11	6.80	12.8
6	7	813	821	15.11	.02	3.88	6.44	13.0
7	113	108	192	0.00	R	R	R	13.0
8	19	482	629	18.33	.06	3.08	6.60	13.0
9	30	479	557	13.82	.11	3.52	6.73	12.0
10	54	373	432	9.19	.26	3.54	6.74	12.0
11	104	356	248	4.54	.87	5.46	6.81	12.0
12	228	364	116	.38	21.35	67.86	35.58	11.1
13	163	137	158	0.00	R	R	R	11.1

CYCLE COMPOSITE BSHC = .447 GRAM/KW HR
BSCO+ = 3.896 GRAM/KW HR
BSNO2++= 7.127 GRAM/KW HR
BSHC + BSNO2++= 7.574 GRAM/KW HR
BSFC = .273KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

Table D-10. 21-MODE EPA EXP DIESEL EMISSION CYCLE

CATERPILLAR 3406 DIESEL ENGINE, DIRECT INJECTION, 33 DEG,BTDC
TEST 1 RUN 1 FUEL: EM-272-F PROJECT: 11-4623-001 TEST DATE 12-16-77

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.031	5.35	5.39	.006
2	1260	28.5	3.8	.079	9.27	9.35	.008
3	1260	109.2	14.4	.110	9.36	9.47	.012
4	1260	246.9	32.6	.172	9.60	9.77	.018
5	1260	341.8	45.1	.215	9.68	9.90	.022
6	1260	683.7	90.2	.364	10.66	11.02	.034
7	1260	1025.5	135.3	.522	12.15	12.67	.043
8	1260	1120.5	147.8	.569	12.51	13.08	.045
9	1260	1258.2	166.0	.646	13.55	14.19	.048
10	1260	1376.9	181.7	.722	14.48	15.20	.050
11	700	0.0	0.0	.024	5.04	5.06	.005
12	2100	1108.6	243.8	.968	22.27	23.24	.043
13	2100	1035.0	227.6	.883	21.49	22.37	.041
14	2100	923.4	203.1	.800	20.55	21.35	.039
15	2100	845.1	185.8	.739	19.73	20.47	.037
16	2100	562.6	123.7	.533	17.13	17.66	.031
17	2100	282.5	62.1	.339	15.55	15.89	.022
18	2100	201.8	44.4	.283	15.13	15.41	.019
19	2100	90.2	19.8	.208	14.46	14.67	.014
20	2100	21.4	4.7	.165	14.47	14.63	.011
21	700	0.0	0.0	.026	5.52	5.55	.005

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	330	1192	116	0.00	R	R	R	9.9
2	274	994	252	.27	19.84	143.50	59.68	9.9
3	260	751	495	1.05	4.97	28.59	30.97	9.9
4	245	348	1215	1.99	2.14	6.06	34.72	9.9
5	246	239	1576	1.62	1.57	3.04	32.95	9.9
6	134	305	1749	6.58	.48	2.16	20.94	9.9
7	86	992	1744	0.00	I	I	I	9.9
8	67	1362	1619	7.24	.17	6.99	13.64	9.9
9	49	1826	1512	0.00	I	I	I	9.9
10	27	2140	1462	0.00	I	I	I	9.9
11	346	1221	95	0.00	R	R	R	10.1
12	59	378	1687	7.80	.16	2.09	15.32	10.1
13	48	363	1706	15.25	.14	2.07	15.97	10.1
14	45	355	1658	8.73	.14	2.16	16.60	10.1
15	51	340	1576	13.57	.16	2.17	16.53	10.1
16	68	263	1356	9.03	.28	2.18	18.44	10.1
17	88	251	1062	0.00	I	I	I	10.1
18	98	297	870	3.51	.99	5.99	28.79	9.8
19	135	434	569	0.00	I	I	I	9.8
20	179	581	380	0.00	I	I	I	9.8
21	299	1167	119	0.00	R	R	R	9.8

CYCLE COMPOSITE BSHC = .628 GRAM/KW HR
BSCO+ = 5.049 GRAM/KW HR
BSNO2++= 18.564 GRAM/KW HR
BSHC + BSNO2++= 19.192 GRAM/KW HR
BSFC = .261KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

Table D-11. 21-MODE EPA EXP DIESEL EMISSION CYCLE

CATERPILLAR 3406 DIESEL ENGINE, DIRECT INJECTION, 33 DEG,BTDC
TEST 1 RUN 2 FUEL: EM-272-F PROJECT: 11-4623-001 TEST DATE 12-19-77

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.030	5.15	5.18	.006
2	1260	28.5	3.8	.079	9.69	9.77	.008
3	1260	109.2	14.4	.112	9.75	9.86	.011
4	1260	246.9	32.6	.175	9.87	10.05	.018
5	1260	344.2	45.4	.215	9.95	10.17	.022
6	1260	686.1	90.5	.362	11.04	11.40	.033
7	1260	1030.3	135.9	.523	12.44	12.96	.042
8	1260	1132.4	149.4	.575	12.89	13.46	.045
9	1260	1265.3	166.9	.650	13.70	14.35	.047
10	1260	1381.6	182.3	.723	14.76	15.48	.049
11	700	0.0	0.0	.030	5.05	5.08	.006
12	2100	1125.2	247.4	.954	22.71	23.66	.042
13	2100	1039.8	228.6	.888	21.93	22.82	.040
14	2100	925.8	203.6	.802	20.96	21.77	.038
15	2100	847.5	186.4	.739	20.30	21.04	.036
16	2100	565.0	124.2	.536	17.93	18.47	.030
17	2100	284.9	62.6	.339	15.84	16.18	.021
18	2100	204.2	44.9	.284	15.56	15.84	.018
19	2100	90.2	19.8	.207	15.00	15.21	.014
20	2100	19.0	4.2	.173	15.00	15.17	.012
21	700	0.0	0.0	.036	5.51	5.55	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	368	1126	95	0.00	R	R	R	10.0
2	308	1065	212	.27	23.31	160.65	52.46	10.0
3	274	815	427	1.05	5.46	32.34	27.80	10.0
4	250	344	1095	1.49	2.24	6.14	32.17	10.0
5	232	285	1548	1.63	1.51	3.70	33.00	10.0
6	140	340	1808	6.61	.51	2.48	21.69	10.0
7	70	443	1670	0.00	I	I	I	10.0
8	41	1242	1559	7.32	.11	6.49	13.38	10.0
9	24	1670	1436	0.00	I	I	I	10.0
10	9	1873	1430	0.00	I	I	I	10.0
11	372	461	94	0.00	R	R	R	10.0
12	32	327	1694	7.92	.09	1.61	15.43	10.0
13	29	301	1674	15.32	.08	1.74	15.91	9.8
14	34	276	1594	8.75	.11	1.71	16.23	9.8
15	40	277	1488	13.60	.13	1.81	16.00	9.8
16	56	225	1261	9.07	.24	1.44	17.86	9.8
17	77	229	1017	0.00	I	I	I	9.8
18	86	230	811	3.55	.88	4.71	27.25	9.8
19	128	318	538	0.00	I	I	I	9.8
20	173	460	351	0.00	I	I	I	9.8
21	382	1069	99	0.00	R	R	R	9.8

CYCLE COMPOSITE
BSHC = .632 GRAM/KW HR
BSCO+ = 4.692 GRAM/KW HR
BSNO2++= 18.162 GRAM/KW HR
BSHC + BSNO2++= 18.794 GRAM/KW HR
BSFC = .261KG/KW HR

+ CONVERTED TO WET BASIS

++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

Table D-12. 13-MODE FEDERAL DIESEL EMISSION CYCLE

CATERPILLAR 3406 DIESEL ENGINE, DIRECT INJECTION, 33 DEG. BTDC
TEST 1 RUN 1 FUEL: EM-272-F PROJECT: 11-4623-001 TEST DATE 12-16-77

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.031	5.35	5.39	.006
2	1260	28.5	3.8	.079	9.27	9.35	.008
3	1260	341.8	45.1	.215	9.68	9.90	.022
4	1260	683.7	90.2	.364	10.66	11.02	.034
5	1260	1025.5	135.3	.522	12.15	12.67	.043
6	1260	1376.9	181.7	.722	14.48	15.20	.050
7	700	0.0	0.0	.024	5.04	5.06	.005
8	2100	1108.6	243.8	.968	22.27	23.24	.043
9	2100	845.1	185.8	.739	19.73	20.47	.037
10	2100	562.6	123.7	.533	17.13	17.66	.031
11	2100	282.5	62.1	.339	15.55	15.89	.022
12	2100	21.4	4.7	.165	14.47	14.63	.011
13	700	0.0	0.0	.026	5.52	5.55	.005

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	330	1192	101	0.00	R	R	R	9.9
2	274	994	245	.30	19.84	143.50	58.06	9.9
3	246	239	1686	3.61	1.57	3.04	35.24	9.9
4	134	305	1886	7.22	.48	2.16	21.95	9.9
5	86	492	1828	10.82	.23	5.39	16.31	9.9
6	27	2140	1569	14.53	.07	10.38	12.51	9.9
7	346	1221	94	0.00	R	R	R	10.1
8	59	378	1831	19.50	.16	2.09	16.62	10.1
9	51	340	1727	14.87	.16	2.17	18.11	10.1
10	68	263	1481	9.90	.28	2.18	20.13	10.1
11	88	251	1113	4.97	.66	3.73	27.12	10.1
12	179	581	400	.38	16.22	104.89	118.74	9.8
13	299	1167	127	0.00	R	R	R	9.8

CYCLE COMPOSITE BSHC = .540 GRAM/KW HR
BSCO+ = 5.872 GRAM/KW HR
BSNO2++= 19.100 GRAM/KW HR
BSHC + BSNO2++= 19.640 GRAM/KW HR
BSFC = .263KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

Table D-13. 13-MODE FEDERAL DIESEL EMISSION CYCLE

CATERPILLAR 3406 DIESEL ENGINE, DIRECT INJECTION, 33 DEG. BTDC
TEST 1 RUN 2 FUEL: EM-272-F PROJECT: 11-4623-001 TEST DATE 12-19-77

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	700	0.0	0.0	.030	5.15	5.18	.006
2	1260	28.5	3.8	.079	9.69	9.77	.008
3	1260	344.2	45.4	.215	9.95	10.17	.022
4	1260	686.1	90.5	.362	11.04	11.40	.033
5	1260	1030.3	135.9	.523	12.44	12.96	.042
6	1260	1381.6	182.3	.723	14.76	15.48	.049
7	700	0.0	0.0	.030	5.05	5.08	.006
8	2100	1125.2	247.4	.954	22.71	23.66	.042
9	2100	847.5	186.4	.739	20.30	21.04	.036
10	2100	565.0	124.2	.536	17.93	18.47	.038
11	2100	284.9	62.6	.339	15.84	16.18	.021
12	2100	19.0	4.2	.173	15.00	15.17	.012
13	700	0.0	0.0	.036	5.51	5.55	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	368	1126	65	0.00	H	R	R	10.0
2	308	1065	192	.30	23.31	160.65	47.54	10.0
3	232	285	1559	3.63	1.51	3.70	33.25	10.0
4	140	340	1782	7.24	.51	2.48	21.37	10.0
5	70	943	1644	10.87	.19	5.21	15.38	10.0
6	9	1873	1433	14.58	.02	9.22	11.59	10.0
7	392	961	68	0.00	H	R	R	10.0
8	32	327	1755	19.79	.09	1.81	15.98	10.0
9	40	277	1557	14.91	.13	1.81	16.75	9.8
10	56	225	1340	9.94	.24	1.94	18.98	9.8
11	77	229	1054	5.01	.58	3.43	25.92	9.8
12	173	460	332	.33	18.29	96.82	114.79	9.8
13	382	1069	88	0.00	H	R	R	9.8

CYCLE COMPOSITE
BSHC = .526 GRAM/KW HR
BSCO+ = 5.395 GRAM/KW HR
BSNO2++= 17.969 GRAM/KW HR
BSHC + BSNO2++= 18.495 GRAM/KW HR
BSFC = .262KG/KW HR

+ CONVERTED TO WET BASIS

++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

Table D-14. 21-MODE EPA EXP DIESEL EMISSION CYCLE

PROJECT: 11-4623-001 TEST DATE 4-12-78 TEST NO.1
ENGINE: CATERPILLAR 3406 INDIRECT INJECTION FUEL EM-329-F

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	600	0.0	0.0	.026	4.23	4.26	.006
2	1400	26.1	3.8	.097	10.00	10.10	.010
3	1400	106.8	15.7	.129	9.87	10.00	.013
4	1400	239.8	35.1	.186	10.15	10.34	.018
5	1400	334.7	49.1	.228	10.36	10.59	.022
6	1400	667.1	97.8	.389	11.91	12.30	.033
7	1400	1001.8	146.9	.586	14.66	15.25	.040
8	1400	1094.4	160.4	.644	15.47	16.12	.042
9	1400	1227.3	179.9	.726	16.40	17.12	.044
10	1400	1343.6	197.0	.812	17.28	18.09	.047
11	600	0.0	0.0	.026	4.76	4.79	.005
12	2100	1113.4	244.8	1.037	24.41	25.44	.042
13	2100	1030.3	226.5	.963	23.37	24.33	.041
14	2100	918.7	202.0	.858	21.67	22.53	.040
15	2100	840.4	184.8	.777	20.62	21.40	.038
16	2100	560.2	123.2	.541	16.75	17.29	.032
17	2100	280.1	61.6	.337	14.65	14.99	.023
18	2100	199.4	43.8	.287	14.24	14.53	.020
19	2100	92.6	20.4	.224	13.83	14.06	.016
20	2100	19.0	4.2	.177	13.83	14.01	.013
21	600	0.0	0.0	.031	4.76	4.79	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	120	411	82	0.00	R	R	R	6.2
2	148	464	73	.28	11.36	70.96	18.24	6.2
3	112	433	135	1.14	2.08	16.03	8.23	6.2
4	72	260	301	2.14	.62	4.44	8.44	6.2
5	56	173	415	1.77	.35	2.17	8.53	6.2
6	28	114	472	7.14	.10	.83	5.65	6.2
7	12	194	500	0.00	I	I	I	6.2
8	30	221	533	7.86	.09	1.29	5.10	6.2
9	4	327	550	0.00	I	I	I	6.6
10	6	377	581	0.00	I	I	I	6.6
11	68	496	93	0.00	R	R	R	6.6
12	24	166	699	7.83	.07	1.00	6.92	6.6
13	24	166	700	15.18	.08	1.04	7.16	6.6
14	32	167	650	8.69	.10	1.08	6.90	6.7
15	40	140	600	13.49	.13	.94	6.61	6.7
16	12	85	533	8.99	.05	.69	7.12	6.4
17	28	116	428	0.00	I	I	I	6.4
18	32	145	337	3.46	.31	2.79	10.62	6.4
19	44	204	208	0.00	I	I	I	6.4
20	60	292	141	0.00	I	I	I	6.4
21	96	382	69	0.00	R	R	R	6.4

```
CYCLE COMPOSITE   BSHC    =   .234   GRAM/KW  HR
                  BSCO+   =  2.049   GRAM/KW  HR
                  BSNO2++=  7.059   GRAM/KW  HR
           BSHC + BSNO2++=  7.292   GRAM/KW  HR
                  BSFC    =   .275KG/KW HR
```

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

Table D-15. 21-MODE EPA EXP DIESEL EMISSION CYCLE

PROJECT: 11-4623-001 TEST DATE 4-12-78 TEST NO.2
ENGINE: CATERPILLAR 3406 INDIRECT INJECTION FUEL EM-329-F

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	600	0.0	0.0	.030	4.41	4.44	.007
2	1400	23.7	3.5	.095	9.88	9.97	.010
3	1400	106.8	15.7	.129	9.94	10.07	.013
4	1400	239.8	35.1	.185	10.07	10.25	.018
5	1400	337.1	49.4	.229	10.28	10.51	.022
6	1400	671.8	98.5	.393	11.97	12.37	.033
7	1400	1004.2	147.2	.587	14.72	15.31	.040
8	1400	1099.1	161.1	.644	15.32	15.97	.042
9	1400	1236.8	181.3	.732	16.45	17.19	.044
10	1400	1353.1	198.4	.816	17.40	18.22	.047
11	600	0.0	0.0	.029	4.55	4.58	.006
12	2100	1106.2	243.2	1.037	24.32	25.35	.043
13	2100	1023.2	225.0	.959	23.10	24.06	.041
14	2100	914.0	201.0	.854	21.98	22.83	.039
15	2100	835.6	183.7	.777	20.47	21.25	.038
16	2100	557.9	122.7	.543	16.93	17.48	.032
17	2100	280.1	61.6	.339	14.41	14.75	.024
18	2100	199.4	43.8	.284	14.03	14.31	.020
19	2100	90.2	19.8	.219	13.75	13.96	.016
20	2100	23.7	5.2	.180	13.62	13.80	.013
21	600	0.0	0.0	.029	4.53	4.56	.006

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	62	226	86	0.00	R	R	R	6.4
2	120	287	72	.25	10.01	47.73	19.77	6.4
3	78	224	136	1.14	1.46	8.34	8.33	6.4
4	50	67	292	2.14	.42	1.13	8.11	6.4
5	42	13	388	1.78	.26	.16	7.85	6.4
6	24	57	452	7.19	.09	.42	5.41	6.6
7	16	84	476	0.00	I	I	I	6.6
8	10	139	517	7.89	.03	.80	4.88	6.6
9	9	219	536	0.00	I	I	I	6.6
10	6	377	543	0.00	I	I	I	6.6
11	56	353	98	0.00	R	R	R	7.2
12	23	166	659	7.78	.07	1.00	6.54	7.2
13	27	166	678	15.07	.08	1.03	6.90	7.2
14	34	167	630	8.64	.11	1.10	6.82	7.2
15	32	113	590	13.41	.11	.75	6.50	6.6
16	20	57	526	8.95	.08	.47	7.14	6.6
17	30	87	400	0.00	I	I	I	6.6
18	35	117	308	3.46	.33	2.21	9.58	6.0
19	44	175	195	0.00	I	I	I	6.0
20	55	234	138	0.00	I	I	I	6.0
21	84	325	63	0.00	R	R	R	6.0

```
CYCLE COMPOSITE   BSHC    =   .193   GRAM/KW  HR
                  BSCO+   =  1.413   GRAM/KW  HR
                  BSNO2++=   6.830   GRAM/KW  HR
           BSHC + BSNO2++=   7.022   GRAM/KW  HR
                  BSFC    =   .275KG/KW HR
```

+ CONVERTED TO WET BASIS

++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

Table D-16. 13-MODE FEDERAL DIESEL EMISSION CYCLE

PROJECT: 11-4623-001 TEST DATE 4-12-78 TEST NO.1
ENGINE: CATERPILLAR 3406 INDIRECT INJECTION FUEL EM-329-F

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	600	0.0	0.0	.026	4.23	4.26	.006
2	1400	26.1	3.8	.097	10.00	10.10	.010
3	1400	334.7	49.1	.228	10.36	10.59	.022
4	1400	667.1	97.8	.389	11.91	12.30	.033
5	1400	1001.8	146.9	.586	14.66	15.25	.040
6	1400	1343.6	197.0	.809	17.28	18.09	.047
7	600	0.0	0.0	.026	4.76	4.79	.005
8	2100	1113.4	244.8	1.037	24.41	25.44	.042
9	2100	840.4	184.8	.777	20.62	21.40	.038
10	2100	560.2	123.2	.541	16.75	17.29	.032
11	2100	280.1	61.6	.337	14.65	14.99	.023
12	2100	19.0	4.2	.177	13.83	14.01	.013
13	600	0.0	0.0	.031	4.76	4.79	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	120	411	63	0.00	R	R	R	6.2
2	148	464	63	.31	11.36	70.96	15.73	6.2
3	56	173	435	3.93	.35	2.17	8.94	6.2
4	28	114	517	7.82	.10	.83	6.19	6.2
5	12	194	582	11.75	.04	1.17	5.75	6.2
6	6	377	626	15.76	.02	2.01	5.47	6.6
7	68	496	83	0.00	R	R	R	6.6
8	24	166	735	19.59	.07	1.00	7.27	6.6
9	40	140	611	14.78	.13	.94	6.74	6.7
10	12	85	517	9.86	.05	.69	6.91	6.4
11	28	116	423	4.93	.20	1.64	9.80	6.4
12	60	292	118	.33	5.86	56.82	37.80	6.4
13	96	382	45	0.00	R	R	R	6.4

CYCLE COMPOSITE BSHC = .176 GRAM/KW HR
BSCO+ = 1.939 GRAM/KW HR
BSNO2++= 6.950 GRAM/KW HR
BSHC + BSNO2++= 7.126 GRAM/KW HR
BSFC = .272KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

Table D-17. 13-MODE FEDERAL DIESEL EMISSION CYCLE

PROJECT: 11-4623-001 TEST DATE 4-12-78 TEST NO.2
ENGINE: CATERPILLAR 3406 INDIRECT INJECTION FUEL EM-329-F

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	600	0.0	0.0	.030	4.41	4.44	.007
2	1400	23.7	3.5	.095	9.88	9.97	.010
3	1400	337.1	49.4	.229	10.28	10.51	.022
4	1400	671.8	98.5	.393	11.37	12.37	.033
5	1400	1004.2	147.2	.587	14.72	15.31	.040
6	1400	1353.1	198.4	.816	17.40	18.22	.047
7	600	0.0	0.0	.029	4.55	4.58	.006
8	2100	1106.2	243.2	1.037	24.32	25.35	.043
9	2100	835.6	183.7	.777	20.47	21.25	.038
10	2100	557.9	122.7	.543	16.93	17.48	.032
11	2100	280.1	61.6	.339	14.41	14.75	.024
12	2100	23.7	5.2	.180	13.62	13.80	.013
13	600	0.0	0.0	.029	4.53	4.56	.006

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	62	226	54	0.00	R	R	R	6.4
2	120	287	53	.28	10.01	47.73	14.58	6.4
3	42	13	389	3.95	.26	.16	7.87	6.4
4	24	57	496	7.88	.09	.42	5.93	6.6
5	16	84	560	11.78	.05	.51	5.55	6.6
6	6	377	577	15.87	.02	2.01	5.04	6.6
7	56	353	55	0.00	R	R	R	7.0
8	23	166	697	19.46	.07	1.00	6.92	7.0
9	32	113	635	14.70	.11	.75	7.00	6.6
10	20	57	555	9.81	.08	.47	7.53	6.6
11	30	87	433	4.93	.21	1.20	9.88	6.6
12	55	234	134	.42	4.23	35.92	33.81	6.0
13	84	325	53	0.00	R	R	R	6.0

CYCLE COMPOSITE
BSHC = .153 GRAM/KW HR
BSCO+ = 1.428 GRAM/KW HR
BSNO2++= 6.806 GRAM/KW HR
BSHC + BSNO2++= 6.959 GRAM/KW HR
BSFC = .273KG/KW HR

* CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE D-18. SUMMARY OF EXHAUST PARTICULATE FROM CATERPILLAR 3406
28° (STANDARD TIMING)

Engine rpm/load %	Run	Concentration mg/m³	Particulate Rate g/hr	Particulate Rate g/kg fuel	Particulate Rate g/kw-hr
1260/02	1	25.86	12.80	3.37	2.84
	2	24.17	12.00	3.16	2.73
	3	22.56	11.16	2.94	2.54
	Avg	24.20	11.99	3.16	2.70
1260/25	1	26.91	13.95	1.08	0.28
	2	25.50	13.26	1.03	0.27
	3	25.16	13.04	1.01	0.26
	Avg	25.86	13.42	1.04	0.27
1260/50	1	42.64	24.90	1.10	0.25
	2	40.79	23.76	1.06	0.24
	3	42.89	24.53	1.10	0.25
	Avg	42.11	24.40	1.09	0.25
1260/75	1	61.36	40.86	1.25	0.28
	2	67.34	44.70	1.36	0.30
	3	62.80	41.85	1.28	0.28
	Avg	63.83	42.47	1.30	0.28
1260/100	1	132.75	99.48	2.34	0.52
	2	132.94	101.69	2.35	0.52
	3	124.49	94.90	2.20	0.49
	Avg	130.06	98.69	2.30	0.51
Idle	1	29.55	7.81	5.21	----
	2	31.76	8.40	5.60	----
	3	29.90	7.92	5.28	----
	Avg	30.40	8.04	5.36	----
2100/100	1	89.88	108.64	1.91	0.44
	2	84.68	101.69	1.78	0.42
	3	85.10	100.76	1.77	0.41
	Avg	86.55	103.70	1.82	0.42
2100/75	1	57.68	60.46	1.39	0.33
	2	57.58	60.70	1.40	0.33
	3	59.93	63.31	1.47	0.34
	Avg	58.40	61.49	1.42	0.33
2100/50	1	66.19	65.05	2.04	0.52
	2	71.61	71.47	2.23	0.58
	3	67.41	69.48	2.18	0.56
	Avg	68.40	68.67	2.15	0.55
2100/25	1	56.85	42.92	2.15	0.69
	2	57.72	47.05	2.35	0.76
	3	52.64	46.28	2.31	0.75
	Avg	55.74	45.42	2.27	0.73
2100/02	1	34.24	25.56	2.64	4.92
	2	41.98	31.20	3.22	6.00
	3	44.36	32.97	3.40	6.34
	Avg	40.19	29.91	3.09	5.75

TABLE D-19. SUMMARY OF EXHAUST SULFATE
CATERPILLAR 3406, 28° (STANDARD TIMING)

Engine rpm/% Load	Run	Concentration µg/m^3	Sulfates			% Sulfur Recovery
			mg/hr	mg/kg Fuel	mg/kW-hr	
1260/2	1	813.8	402.71	89.49	105.98	1.27
	2	894.9	444.27	100.97	116.91	1.43
	3	799.4	395.56	89.90	104.09	1.27
	Avg	836.0	414.18	93.45	108.99	1.32
1260/25	1	3290.6	1706.48	132.29	34.47	1.88
	2		Filter Lost			
	3	3524.8	1826.44	134.13	36.90	1.90
	Avg	3407.7	1766.46	133.21	35.69	1.89
1260/50	1	4349.2	2540.11	112.39	25.74	1.59
	2	4669.9	2720.20	120.90	27.56	1.71
	3	4717.3	2696.71	121.56	27.34	1.72
	Avg	4578.8	2652.34	118.28	26.88	1.67
1260/75	1	4760.7	3169.88	96.64	21.49	1.37
	2	4056.2	2692.56	82.09	18.25	1.16
	3	3952.2	2633.94	80.55	17.82	1.14
	Avg	4256.4	2832.13	86.43	19.19	1.22
1260/100	1	5066.1	3796.54	89.33	19.98	1.27
	2	5448.0	4167.37	96.47	21.70	1.37
	3	5014.1	3822.18	88.48	19.88	1.25
	Avg	5176.1	3928.70	91.43	20.52	1.30
Idle	1	1694.8	447.83	298.55	------	4.23
	2	1455.4	384.71	256.47	------	3.64
	3	1804.9	478.07	318.71	------	4.52
	Avg	1651.7	436.87	291.24	------	4.13
2100/100	1	4935.2	5965.28	104.65	24.35	1.48
	2	4866.7	5844.24	102.53	23.85	1.45
	3	4943.8	5853.36	103.05	23.94	1.46
	Avg	4915.3	5887.63	103.41	24.05	1.46
2100/75	1	4009.6	4202.54	96.61	22.88	1.37
	2	4231.4	4460.92	103.02	24.28	1.46
	3	4769.3	5038.81	116.91	27.43	1.66
	Avg	4336.8	4567.42	105.51	24.86	1.50
2100/50	1	4800.1	4717.55	147.89	38.04	2.10
	2	4537.8	4528.57	141.52	36.46	2.01
	3	4472.1	4608.98	144.48	37.11	2.05
	Avg	4603.3	4618.37	144.63	37.20	2.05
2100/25	1	2783.9	2269.53	113.48	36.55	1.61
	2	3125.5	2547.68	127.38	41.02	1.81
	3	3558.0	2896.62	144.83	46.64	2.05
	Avg	3155.8	2571.28	128.56	41.40	1.82
2100/2	1	1712.4	1249.32	128.80	240.25	1.83
	2	2099.9	1560.73	160.90	300.14	2.28
	3	1914.0	1422.64	146.66	273.58	2.08
	Avg	1908.8	1410.90	145.45	271.32	2.06

TABLE D-20. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CATERPILLAR 3406 DI 28° (Run 1)
(13-Mode FTP Weighting Factors)

							Weighted			
rpm	% Load	Power kw	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Power kw	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr
700	--	--	1.8	7.81	447.83	0.067	--	0.121	0.523	30.01
1260	2	3.8	4.5	12.80	402.71	0.08	0.304	0.360	1.024	32.22
1260	25	49.5	12.9	13.95	1706.48	0.08	3.960	1.032	1.116	136.52
1260	50	98.7	22.6	24.90	2540.11	0.08	7.896	1.808	1.992	203.21
1260	75	147.5	32.8	40.86	3169.88	0.08	11.800	2.624	3.26	253.59
1260	100	189.5	42.5	99.48	3796.54	0.08	15.16	3.40	7.95	303.72
700	--	--	1.8	7.81	447.83	0.067	--	0.121	0.52	30.01
2100	100	244.5	57.0	108.64	5965.28	0.08	19.56	4.56	8.69	477.22
2100	75	183.7	43.5	60.46	4202.54	0.08	14.70	3.48	4.83	336.20
2100	50	124.2	31.9	65.05	4717.55	0.08	9.936	2.552	5.20	377.40
2100	25	62.1	20.0	42.92	2269.53	0.08	4.968	1.600	3.43	181.56
2100	2	5.2	9.7	25.56	1249.32	0.08	0.416	0.776	2.04	99.95
700	--	--	1.8	7.81	447.83	0.067	--	0.121	0.52	30.01
							88.70	22.555	41.139	2491.62

Brake Specific Particulate, g/kw-hr 0.464
Fuel Specific Particulate, g/kg fuel 1.824

Brake Specific $SO_4^=$, mg/kw-hr 28.09
Fuel Specific $SO_4^=$, mg/kg fuel 110.47

TABLE D-21. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CATERPILLAR 3406 DI 28° BTDC (Run 2)
(13-Mode FTP Weighting Factors)

							Weighted			
rpm	% Load	Power kw	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Power kw	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr
700	---	-----	1.8	8.40	384.71	0.067	-----	0.121	0.563	25.78
1260	2	3.8	4.4	12.00	444.27	0.08	0.304	0.352	0.960	35.54
1260	25	49.5	12.9	13.26	-------	0.08	3.96	1.032	1.061	-------
1260	50	98.7	22.5	23.76	2720.20	0.08	7.90	1.80	1.901	217.62
1260	75	147.5	32.8	44.70	2692.56	0.08	11.80	2.624	3.576	215.40
1260	100	192.0	43.2	101.69	4167.37	0.08	15.36	3.456	8.135	333.39
700	---	-----	1.8	8.40	384.71	0.067	-----	0.121	0.563	25.78
2100	100	245.0	57.0	101.69	5844.24	0.08	19.6	4.56	8.135	467.54
2100	75	183.7	43.3	60.7	4460.92	0.08	14.70	3.464	4.856	356.87
2100	50	124.2	32.1	71.47	4528.57	0.08	9.94	2.568	5.718	362.29
2100	25	62.1	20.0	47.05	2547.68	0.08	4.97	1.600	3.764	203.81
2100	2	5.2	9.7	31.20	1560.73	0.08	0.42	0.776	2.496	124.86
700	---	-----	1.8	8.40	384.71	0.067	-----	0.121	0.563	25.78
							88.95	22.595	42.291	2394.66

Brake Specific Particulate, g/kw-hr 0.475 Brake Specific $SO_4^=$, mg/kW-hr 28.18
Fuel Specific Particulate, g/kg fuel 1.872 Fuel Specific $SO_4^=$, mg/kg fuel 111.05

TABLE D-22. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CATERPILLAR 3406 DI 28° BTDC (Run 3)
(13-Mode FTP Weighting Factors)

							Weighted			
rpm	% Load	Power kw	Fuel kg/hr	Part. g/hr	$SO4^=$ mg/hr	Wgt. Fact.	Power kw	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr
700	---	-----	1.8	7.92	478.07	0.067	------	0.121	0.531	32.03
1260	2	3.8	4.4	11.16	395.56	0.08	0.304	0.352	0.893	31.64
1260	25	49.5	12.9	13.04	1826.44	0.08	3.96	1.032	1.043	146.12
1260	50	98.7	22.2	24.53	2696.71	0.08	7.90	1.776	1.962	215.74
1260	75	147.8	32.7	41.85	2633.94	0.08	11.82	2.616	3.348	210.72
1260	100	192.1	43.2	94.90	3822.18	0.08	15.37	3.457	7.59	305.77
700	---	-----	1.8	7.92	478.07	0.067	------	0.121	0.531	32.03
2100	100	244.0	56.8	100.76	5853.36	0.08	19.52	4.544	8.061	468.27
2100	75	183.6	43.1	63.31	5038.81	0.08	14.69	3.448	5.064	403.10
2100	50	124.2	31.9	69.48	4608.98	0.08	9.94	2.552	5.558	368.72
2100	25	62.1	20.0	46.28	2896.62	0.08	4.97	1.60	3.702	231.73
2100	2	5.2	9.7	32.97	1422.64	0.08	0.42	0.776	2.638	113.81
700	---	-----	1.8	7.92	478.07	0.067	-----	0.121	0.531	32.03
							88.894	22.516	41.452	2591.71

Brake Specific Particulate, g/kw-hr 0.466 Brake Specific $SO_4^=$, mg/kW-hr 29.16
Fuel Specific Particulate, g/kg fuel 1.841 Fuel Specific $SO_4^=$, mg/kg fuel 115.11

TABLE D-23. SUMMARY OF EXHAUST PARTICULATE - CATERPILLAR 3406 DI 28°/EGR

Engine rpm/load %	Run	Concentration mg/m^3	Particulate Rate g/hr	Particulate Rate g/kg fuel	Particulate Rate g/kw-hr
1260/02	1	26.58	5.63	1.28	1.37
	2	23.81	5.01	1.14	1.22
	3	21.77	4.67	1.06	1.14
	Avg	24.05	5.10	1.16	1.24
1260/25	1	---	---	---	---
	2	175.39	48.90	3.70	1.00
	3	203.62	57.00	4.25	1.17
	Avg	189.51	52.95	3.98	1.09
1260/50	1	300.591	133.94	5.58	1.36
	2	309.154	135.81	5.61	1.38
	3	272.758	121.15	5.03	1.23
	Avg	441.252	130.30	5.41	1.32
1260/75	1	319.688	189.53	5.24	1.28
	2	340.027	200.60	5.57	1.35
	3	427.070	251.49	7.08	1.70
	Avg	362.26	213.87	5.96	1.44
1260/100	1	247.10	178.61	4.12	0.96
	2	260.07	186.00	4.32	1.01
	3	215.76	156.54	3.64	0.84
	Avg	240.98	173.72	4.03	0.94
Idle	1	23.04	2.80	1.65	----
	2	25.10	3.06	1.80	----
	3	24.50	2.98	1.75	----
	Avg	24.21	2.95	1.73	----
2100/100	1	268.60	266.11	4.66	1.16
	2	232.32	239.57	4.18	1.03
	3	227.57	235.68	4.15	1.01
	Avg	242.83	247.12	4.33	1.07
2100/75	1	300.29	257.86	5.37	1.36
	2	314.32	266.54	5.54	1.41
	3	310.20	262.33	5.45	1.38
	Avg	308.27	262.24	5.45	1.38
2100/50	1	174.20	119.82	3.57	0.95
	2	193.44	132.26	3.94	1.04
	3	237.51	164.27	4.85	1.30
	Avg	201.72	138.78	4.12	1.10
2100/25	1	214.31	106.58	5.05	1.69
	2	210.88	105.79	5.04	1.67
	3	227.88	113.33	5.40	1.79
	Avg	217.69	108.57	5.16	1.72
2100/02	1	83.97	30.23	3.08	5.81
	2	78.03	27.50	2.81	5.85
	3	83.04	28.55	2.94	5.95
	Avg	81.68	28.76	2.94	5.87

TABLE D-24. SUMMARY OF EXHAUST SULFATE
CATERPILLAR 3406, 28°/EGR

Engine rpm/% Load	Run	Concentration µg/m^3	Sulfates			% Sulfur Recovery
			mg/hr	mg/kg Fuel	mg/kW-hr	
1260/2	1	891.1	188.62	42.87	46.01	0.63
	2	1218.7	256.66	58.33	62.60	0.84
	3	1515.6	325.04	73.87	79.28	1.05
	Avg	1208.5	256.77	58.36	62.63	0.84
1260/25	1	------	-------	------	------	----
	2	4597.3	1281.57	97.09	26.21	1.38
	3	4178.3	1169.59	87.28	23.92	1.24
	Avg	4387.8	1225.58	92.19	25.06	1.31
1260/50	1	5455.2	2430.68	101.28	24.63	1.44
	2	4122.6	1811.03	75.15	18.35	1.07
	3	4863.0	2160.03	89.63	21.88	1.27
	Avg	4813.6	2133.91	88.69	21.62	1.26
1260/75	1	4902.7	2906.50	80.51	19.63	1.15
	2	4463.4	2633.28	73.15	17.79	1.04
	3	6178.3	3638.13	102.48	24.56	1.45
	Avg	5181.5	3059.30	85.38	20.66	1.21
1260/100	1	5262.7	3717.70	85.86	19.90	1.25
	2	5515.1	3943.12	91.49	21.31	1.30
	3	5461.8	3962.62	92.15	21.25	1.31
	Avg	5413.2	3874.48	89.83	20.82	1.29
Idle	1	2048.0	249.51	146.77	------	2.09
	2	1625.4	198.30	116.65	------	1.66
	3	1951.5	236.70	139.24	------	1.97
	Avg	1875.0	228.17	134.22	------	1.91
2100/100	1	7204.3	7137.44	125.00	31.14	1.78
	2	7569.3	7805.38	136.22	33.37	1.93
	3	6905.3	7151.28	126.13	30.80	1.80
	Avg	7226.3	7364.70	129.12	31.77	1.84
2100/75	1	6614.5	5681.32	118.36	29.98	1.68
	2	6519.8	5528.74	114.94	29.18	1.60
	3	6781.2	6984.85	145.22	36.86	2.05
	Avg	6638.5	6064.97	126.17	32.01	1.78
2100/50	1	5213.7	3586.34	106.74	28.31	1.51
	2	5363.9	3667.29	109.15	28.92	1.55
	3	7014.6	4851.60	143.12	38.26	2.08
	Avg	5864.1	4035.08	119.67	31.83	1.71
2100/25	1	4850.9	2412.30	114.33	38.17	1.63
	2	3676.4	1844.25	87.82	29.18	1.25
	Avg	4263.7	2128.28	101.08	33.68	1.44
2100/2	1	2523.5	908.52	92.71	174.72	1.31
	2	2363.0	832.71	84.97	177.17	1.21
	3	2782.3	956.42	98.60	199.25	1.41
	Avg	2556.3	899.22	92.09	183.71	1.31

TABLE D-25. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CATERPILLAR 3406 28°/EGR (Run 1)
(13-Mode FTP Weighting Factors)

							Weighted			
rpm	% load	Power kw	Fuel kg/hr	Part. g/hr	SO_4= mg/hr	Wgt. Fact.	Power kw	Fuel kg/hr	Part. g/hr	SO_4= mg/hr
700	---	-----	1.7	2.80	249.51	0.067	-----	0.11	0.19	16.72
1260	2	4.1	4.4	5.63	188.62	0.08	0.33	0.35	0.45	15.09
1260	25	-----	---	-- ---	-------	-----	-----	----	-----	------
1260	50	98.7	24.0	133.94	2430.68	0.08	7.90	1.92	10.72	194.45
1260	75	148.1	36.2	189.53	2906.50	0.08	11.85	2.90	15.16	232.52
1260	100	186.8	43.3	178.61	3717.70	0.08	14.94	3.46	14.29	297.42
700	---	------	1.7	2.80	249.51	0.067	-----	0.11	0.19	16.72
2100	100	229.2	57.1	266.11	7137.44	0.08	18.34	4.57	21.29	571.00
2100	75	189.5	48.0	257.86	5681.32	0.08	15.16	3.84	20.63	454.51
2100	50	126.7	33.6	119.82	3586.34	0.08	10.14	2.69	9.59	286.91
2100	25	63.2	21.1	106.58	2412.30	0.08	5.06	1.69	8.53	192.98
2100	2	5.2	9.8	30.23	908.52	0.08	0.42	0.78	2.42	72.68
700	---	-----	1.7	2.80	249.51	0.067	-----	0.11	0.19	16.72
										2367.72
							84.14	22.53	103.65	

Brake Specific Particulate, g/kw-hr 1.232
Fuel Specific Particulate, g/kg fuel 4.600

Brake Specific SO_4=, mg/kw-hr 28.14
Fuel Specific SO_4=, mg/kg fuel 105.09

TABLE D-26. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CATERPILLAR 3406 DI 28°/EGR (Run 2)
(13-Mode FTP Weighting Factors)

							Weighted			
rpm	% load	Power kw	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Power kw	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr
700	---	-----	1.7	3.06	198.30	0.067	-----	0.11	0.21	13.29
1260	2	4.1	4.4	5.01	256.66	0.08	0.33	0.35	0.40	20.53
1260	25	48.9	13.2	48.90	1281.57	0.08	3.91	1.06	3.91	102.53
1260	50	98.7	24.2	135.81	1811.03	0.08	7.90	1.94	10.86	144.88
1260	75	148.1	36.0	200.60	2633.28	0.08	11.85	2.88	16.05	210.66
1260	100	185.0	43.1	186.00	3943.12	0.08	14.80	3.45	14.88	315.45
700	---	-----	1.7	3.06	198.30	0.067	-----	0.11	0.21	13.29
2100	100	233.6	57.3	239.57	7805.38	0.08	18.69	4.58	19.17	624.43
2100	75	189.5	48.1	266.54	5528.74	0.08	15.16	3.85	21.32	442.30
2100	50	126.8	33.6	132.26	3667.29	0.08	10.14	2.69	10.58	293.38
2100	25	63.2	21.0	105.79	1844.25	0.08	5.06	1.68	8.46	147.54
2100	2	4.7	9.8	27.50	832.71	0.08	0.38	0.78	2.20	66.62
700	---	-----	1.7	3.06	198.30	0.067	-----	0.11	0.21	13.29
							88.22	23.59	108.46	2408.19

Brake Specific Particulate, g/kw-hr	1.229	Brake Specific $SO_4^=$, mg/kW-hr	27.30
Fuel Specific Particulate, g/kg fuel	4.598	Fuel Specific $SO_4^=$, mg/kg fuel	102.09

TABLE D-27. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CATERPILLAR 3406 DI 28°/EGR (Run 3)
(13-Mode FTP Weighting Factors)

							Weighted			
rpm	% Load	Power kw	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Power kw	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr
700	---	-----	1.7	2.98	236.70	0.067	-----	0.11	0.20	15.86
1260	2	4.1	4.4	4.67	325.04	0.08	0.33	0.35	0.37	26.00
1260	25	48.9	13.4	57.00	1169.59	0.08	3.91	1.07	4.56	93.57
1260	50	98.7	24.1	121.15	2160.03	0.08	7.90	1.93	9.69	172.80
1260	75	148.1	35.5	251.49	3638.13	0.08	11.85	2.84	20.12	291.05
1260	100	186.5	43.0	156.54	3962.62	0.08	14.92	3.44	12.52	317.01
700	---	-----	1.7	2.98	236.70	0.067	-----	0.11	0.20	15.86
2100	100	232.2	56.8	235.68	7151.28	0.08	18.58	4.54	18.85	572.10
2100	75	189.5	48.1	262.33	6984.85	0.08	15.16	3.85	20.99	558.79
2100	50	126.8	33.9	164.27	4851.60	0.08	10.14	2.71	13.14	388.13
2100	25	63.2	21.0	113.33	-------	0.08	5.06	1.68	9.07	------
2100	2	4.8	9.7	28.55	956.42	0.08	0.38	0.78	2.28	76.51
700	---	-----	1.7	2.98	236.70	0.067	-----	0.11	0.20	15.86
							88.23	23.52	112.19	2543.54

Brake Specific Particulate, g/kw-hr	1.272	Brake Specific $SO_4^=$, mg/kW-hr	30.58
Fuel Specific Particulate, g/kg fuel	4.770	Fuel Specific $SO_4^=$, mg/kg fuel	116.46

TABLE D-28. SUMMARY OF EXHAUST PARTICULATE - CATERPILLAR 3406 18° (10° RETARD)

Engine rpm/load %	Run	Concentration mg/m^3	Particulate Rate g/hr	g/kg Fuel	g/kw-hr
1260/2	1	26.29	12.66	2.88	3.33
	2	17.48	8.61	1.79	2.27
	3	24.18	11.90	2.53	3.50
	Avg	22.65	11.06	2.40	3.03
2160/25	1	93.96	49.83	3.86	1.03
	2	97.82	51.26	3.97	1.06
	3	100.79	73.17	5.38	1.51
	Avg	97.52	58.09	4.40	1.20
1260/50	1	ND	ND	ND	ND
	2	150.76	90.23	3.96	0.93
	3	151.90	89.83	4.03	0.95
	Avg	151.33	90.03	4.00	0.94
1260/75	1	273.97	184.99	5.62	1.31
	2	272.26	184.87	5.64	1.31
	3	281.29	189.81	5.79	1.34
	Avg	275.84	186.56	5.68	1.32
1260/100	1	374.90	294.52	6.62	1.59
	2	434.88	339.62	7.68	1.85
	3	436.86	339.29	7.66	1.85
	Avg	415.55	324.48	7.32	1.76
Idle	1	19.86	5.76	2.88	--
	2	20.78	6.02	2.87	--
	3	23.36	6.79	3.23	--
	Avg	21.33	6.19	2.99	--
2100/100	1	238.17	294.35	5.12	1.32
	2	189.50	239.50	4.09	1.03
	3	179.32	226.38	3.86	0.97
	Avg	202.33	253.41	4.36	1.11
2100/75	1	184.62	202.26	4.55	1.16
	2	177.29	194.87	4.32	1.10
	3	172.64	189.74	4.23	1.08
	Avg	178.18	195.62	4.37	1.11
2100/50	1	154.43	147.46	4.61	1.26
	2	165.72	159.13	4.97	1.36
	3	167.27	161.19	5.05	1.39
	Avg	162.47	155.93	4.88	1.34
2100/25	1	142.24	121.08	5.96	2.09
	2	139.53	119.19	5.84	2.06
	3	142.56	120.67	5.94	2.08
	Avg	141.44	120.31	5.91	2.08
2100/2	1	72.70	56.39	5.47	13.43
	2	79.61	61.64	6.04	14.68
	3	81.20	62.85	6.16	14.96
	Avg	77.84	60.29	5.89	14.36

TABLE D-29. SUMMARY OF EXHAUST SULFATE
CATERPILLAR 3406, 18° (10° RETARD)

Engine rpm/Load %	Run	Concentration µg/m³	Sulfate Rate mg/hr	Sulfate Rate mg/kg Fuel	Sulfate Rate mg/kW-hr	% Sulfur Recovery
1260/2	1	975.8	469.97	106.81	123.68	1.51
	2	1146.2	564.32	117.57	148.51	1.67
	3	1077.3	530.16	112.80	155.93	1.60
	Avg	1066.4	521.48	112.39	142.71	1.59
1260/25	1	3702.9	1963.58	151.04	40.74	2.14
	2	3897.4	2042.10	158.30	42.28	2.24
	3	3990.2	2896.84	213.00	59.85	3.02
	Avg	3863.5	2300.84	174.11	47.62	2.47
1260/50	1	7982.4	4780.36	209.66	49.18	2.97
	2	5919.4	3542.72	155.38	36.49	2.20
	3	5695.4	3368.20	151.04	35.72	2.14
	Avg	6532.4	3897.09	172.03	40.46	2.44
1260/75	1	7725.0	5216.10	137.63	36.92	1.95
	2	6287.5	4269.35	130.16	30.28	1.85
	3	6092.1	4110.95	125.33	29.05	1.77
	Avg	6701.5	4532.13	131.04	32.08	1.86
1260/100	1	5719.6	4493.36	100.97	24.25	1.43
	2	5537.9	4324.75	97.85	23.53	1.39
	3	5581.7	4335.07	97.86	23.61	1.39
	Avg	5613.1	4384.39	98.89	23.80	1.40
Idle	1	1034.5	300.23	150.12	------	2.13
	2	1240.0	359.45	171.17	------	2.43
	3	1124.7	326.99	155.71	------	2.21
	Avg	1133.1	328.89	159.00	------	2.26
2100/100	1	5580.3	6896.68	119.94	31.01	1.70
	2	6540.9	8266.69	141.07	35.65	2.00
	3	6060.0	7650.60	130.33	32.89	1.85
	Avg	6060.4	7604.66	130.45	33.18	1.85
2100/75	1	5659.5	6200.05	135.67	35.49	1.92
	2	6186.4	6799.60	150.77	38.55	2.14
	3	5619.0	6175.77	137.55	35.01	1.95
	Avg	5821.6	6391.81	141.33	36.35	2.00
2100/50	1	4725.4	4512.25	141.01	38.43	2.00
	2	4713.9	4526.45	141.45	38.56	2.01
	3	4570.5	4423.73	138.67	38.14	1.97
	Avg	4669.9	4487.48	140.38	38.38	1.99
2100/25	1	3835.0	3264.48	160.81	56.38	2.28
	2	3498.5	2988.44	146.49	51.61	2.08
	3	3634.4	3076.38	151.55	53.13	2.15
	Avg	3656.0	3109.77	152.95	53.71	2.17
2100/2	1	1555.6	1206.62	118.30	287.29	1.68
	2	1679.7	1300.61	127.51	309.67	1.81
	3	1781.2	1378.78	135.17	328.28	1.92
	Avg	1672.2	1295.34	126.99	308.41	1.80

TABLE D-30. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CATERPILLAR 3406 DI 18° (Run 1)
(13-Mode FTP Weighting Factors)

							Weighted			
rpm	% load	Power kw	Fuel kg/min	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Power kW	Fuel kg/min	Part. g/hr	$SO_4^=$ mg/hr
700	---	-----	2.0	5.76	300.23	0.067	-----	0.134	0.386	20.12
1260	2	3.8	4.4	12.66	469.97	0.08	0.30	0.35	1.013	37.60
1260	25	48.2	12.9	49.83	1963.58	0.08	3.86	1.03	3.986	157.09
1260	50	97.2	22.8	ND	4780.36	0.08	7.78	1.82	-------	382.43
1260	75	141.3	32.9	184.99	5216.10	0.08	11.30	2.63	14.799	417.29
1260	100	185.3	44.5	294.52	4493.36	0.08	14.82	3.56	23.562	359.47
700	---	-----	2.0	5.76	300.26	0.067	-----	0.134	0.386	20.12
2100	100	222.4	57.5	294.35	6896.68	0.08	17.79	4.60	23.548	551.73
2100	75	174.5	44.6	202.26	6200.05	0.08	13.96	3.57	16.181	496.00
2100	50	117.4	32.0	147.46	4512.25	0.08	9.39	2.56	11.797	360.98
2100	25	57.9	20.3	121.08	3264.48	0.08	4.63	1.62	9.686	261.16
2100	2	4.2	10.3	56.39	1206.62	0.08	0.34	0.82	4.511	96.53
700	---	-----	2.0	5.76	300.26	0.067	-----	0.134	0.386	20.12
							84.17	22.96	110.241	3180.64

Brake Specific Particulate, g/kw-hr	1.310
Fuel Specific Partiuclate, g/kg fuel	4.801
Brake Specific $SO_4^=$, mg/kw-hr	37.79
Fuel Specific $SO_4^=$, mg/kg fuel	138.53

TABLE D-31. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CATERPILLAR 3406 DI 18° (Run 2)
(13-Mode FTP Weighting Factors)

							Weighted			
rpm	% load	Power kw	Fuel kg/min	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Power kw	Fuel kg/min	Part. g/hr	$SO_4^=$ mg/hr
700	---	-----	2.1	6.02	359.45	0.067	-----	0.141	0.403	24.08
1260	2	3.8	4.8	8.61	564.32	0.08	0.30	0.38	0.689	45.15
1260	25	48.3	12.9	51.26	2042.10	0.08	3.86	1.03	4.101	163.37
1260	50	97.1	22.8	90.23	3542.72	0.08	7.77	1.82	7.218	283.42
1260	75	141.0	32.8	184.87	4269.35	0.08	11.28	2.62	14.789	341.55
1260	100	183.8	44.2	339.62	4324.75	0.08	14.70	3.54	27.170	345.98
700	---	-----	2.1	6.02	359.45	0.067	-----	0.141	0.403	24.08
2100	100	231.9	58.6	239.50	8266.69	0.08	18.55	4.69	19.160	661.34
2100	75	176.4	45.1	194.87	6799.60	0.08	14.11	3.61	15.590	543.97
2100	50	117.4	32.0	159.13	4526.45	0.08	9.39	2.56	12.730	362.12
2100	25	57.9	20.4	119.19	2988.44	0.08	4.63	1.63	9.535	239.08
2100	2	4.2	10.2	61.64	1300.61	0.08	0.34	0.82	4.931	104.05
700	---	-----	2.1	6.02	359.45	0.067	-----	0.141	0.403	24.08
							84.93	23.123	117.149	3162.27

Brake Specific Particulate, g/kw-hr	1.379	Brake Specific $SO_4^=$, mg/kw-hr	37.23
Fuel Specific Particulate, g/kg fuel	5.066	Fuel Specific $SO_4^=$, mg/kg fuel	136.76

TABLE D-32. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CATERPILLAR 3406 DI 18° (Run 3)
(13-Mode FTP Weighting Factors)

							Weighted			
rpm	% load	Power kw	Fuel kg/min	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Power kW	Fuel kg/min	Part. g/hr	$SO_4^=$ mg/hr
700	---	-----	2.0	6.79	326.99	0.067	-----	0.13	0.455	21.91
1260	2	3.4	4.7	11.90	530.16	0.08	0.27	0.38	0.952	42.41
1260	25	48.5	13.6	73.17	2896.84	0.08	3.88	1.09	5.854	231.75
1260	50	94.3	22.3	89.83	3368.20	0.08	7.54	1.78	7.186	269.46
1260	75	141.5	32.8	189.81	4110.95	0.08	11.32	2.62	15.185	328.88
1260	100	183.6	44.3	339.29	4335.07	0.08	14.69	3.54	27.143	346.81
700	---	-----	2.0	6.79	326.99	0.067	-----	0.13	0.455	21.91
2100	100	232.6	58.7	226.38	7650.60	0.08	18.61	4.70	18.110	612.05
2100	75	176.4	44.9	189.74	6175.77	0.08	14.11	3.59	15.179	494.06
2100	50	116.0	31.9	161.19	4423.73	0.08	9.28	2.55	12.895	353.90
2100	25	57.9	20.3	120.67	3076.38	0.08	4.63	1.62	9.654	246.11
2100	2	4.2	10.2	62.85	1378.78	0.08	0.34	0.82	5.028	110.30
700	---	-----	2.0	6.79	326.99	0.067	-----	0.13	0.455	21.91
							84.67	23.08	118.551	3101.46

Brake Specific Particulate, g/kw-hr	1.400	Brake Specific $SO_4^=$, mg/kw-hr	36.63
Fuel Specific Particulate, g/kg fuel	5.137	Fuel Specific $SO_4^=$, mg/kg fuel	134.38

TABLE D-33. SUMMARY OF EXHAUST PARTICULATE FROM CATERPILLAR 3406
33° TIMING (BASED ON 47 mm GLASSFIBER FILTERS)

Engine rpm/ % load	Run No.	Concentration mg/m³	Particulate Rate g/hr	Particulate Rate g/kg fuel	Particulate Rate g/kW-hr
1260/2	1	39.06	18.83	4.01	4.96
	2	50.13	24.67	4.49	6.49
	3	47.46	23.55	4.81	6.20
	Avg	45.55	22.35	4.44	5.88
1260/25	1	46.52	23.26	1.76	0.50
	2	50.40	26.07	1.93	0.56
	3	48.21	24.78	1.89	0.53
	Avg	48.38	24.70	1.86	0.53
1260/50	1	51.67	29.01	1.30	0.31
	2	52.45	29.68	1.33	0.32
	3	52.68	30.29	1.36	0.32
	Avg	52.27	29.66	1.33	0.32
1260/75	1	49.72	32.84	1.00	0.23
	2	58.80	38.47	1.20	0.27
	3	61.76	40.73	1.26	0.29
	Avg	56.76	37.35	1.15	0.26
1260/100	1	82.88	63.37	1.45	0.34
	2	85.07	65.46	1.50	0.35
	3	99.18	76.26	1.75	0.41
	Avg	89.04	68.36	1.57	0.37
Idle	1	40.81	11.51	5.76	----
	2	44.36	12.59	5.47	----
	3	47.82	13.73	6.24	----
	Avg	44.33	12.61	5.82	----
2100/100	1	56.39	67.21	1.18	0.28
	2	48.42	58.05	1.01	0.24
	3	53.44	63.69	1.13	0.26
	Avg	52.75	62.98	1.11	0.26
2100/75	1	33.58	35.33	0.80	0.19
	2	42.00	44.98	1.01	0.24
	3	37.05	39.58	0.89	0.21
	Avg	37.54	39.96	0.90	0.21
2100/50	1	32.31	29.99	0.93	0.24
	2	31.50	29.54	0.93	0.24
	3	32.24	29.88	0.94	0.25
	Avg	32.02	29.80	0.93	0.24
2100/25	1	27.52	22.76	1.12	0.37
	2	24.92	20.71	1.03	0.34
	3	23.71	19.30	0.96	0.32
	Avg	25.38	20.92	1.04	0.34
2100/2	1	33.53	25.71	2.52	5.47
	2	31.51	24.40	2.46	5.81
	3	28.52	21.76	2.11	4.63
	Avg	31.19	23.96	2.36	5.30

TABLE D-34. SUMMARY OF EXHAUST SULFATE
CATERPILLAR 3406, 33° TIMING (BASED ON 47 mm FLUOROPORE FILTERS)

Engine	Run	Concentration	Sulfate Rate			% Sulfur
rpm/% Load	No.	$\mu g/m^3$	mg/hr	mg/kg Fuel	mg/kW-hr	Recovery
1260/2	1	1871.3	901.88	191.89	237.34	2.72
	2	2596.5	1277.99	232.36	336.31	3.29
	3	2443.9	1212.44	247.44	319.06	3.51
	Avg	2303.9	1130.77	223.90	297.57	3.17
1260/25	1	3387.1	1693.22	126.76	36.26	1.80
	2	3851.2	1992.24	147.57	42.48	2.09
	3	3544.5	1821.93	139.08	39.01	1.97
	Avg	3594.3	1835.80	137.80	39.25	1.95
1260/50	1	7115.3	3995.20	179.16	42.82	2.54
	2	6401.6	3621.28	161.66	38.69	2.29
	3	6558.3	3771.05	169.11	40.38	2.40
	Avg	6691.7	3795.84	169.98	40.63	2.33
1260/75	1	5038.4	3327.95	101.46	23.45	1.44
	2	6397.4	4184.62	130.77	29.83	1.85
	3	6107.8	4027.59	124.31	28.67	1.76
	Avg	5847.9	3846.72	118.85	27.32	1.68
1260/100	1	5907.7	4516.57	103.35	24.23	1.47
	2	6811.4	5240.90	119.93	27.83	1.70
	3	6131.3	4714.03	108.37	25.36	1.54
	Avg	6283.5	4823.83	110.55	25.81	1.57
Idle	1	2472.0	697.25	332.02	------	4.71
	2	3075.1	872.64	379.41	------	5.38
	3	3093.1	888.34	403.79	------	5.73
	Avg	2880.1	819.41	371.74	------	5.27
2100/100	1	5884.1	7013.00	123.47	28.73	1.75
	2	5653.4	6777.53	118.49	27.55	1.68
	3	6068.3	7231.83	128.45	29.95	1.82
	Avg	5868.6	7007.45	123.47	28.74	1.75
2100/75	1	5087.7	5447.43	122.69	29.54	1.74
	2	4777.1	5103.80	114.95	27.68	1.63
	3	4152.7	4370.08	99.32	23.97	1.41
	Avg	4672.5	4973.77	112.32	27.06	1.59
2100/50	1	4358.4	4045.38	125.24	32.94	1.78
	2	4543.8	4262.19	134.03	35.05	1.90
	3	4480.6	4152.15	130.16	34.23	1.85
	Avg	4460.8	4153.24	129.61	34.07	1.84
2100/25	1	3108.4	2570.30	126.62	42.00	1.80
	2	2918.1	2425.11	120.65	40.02	1.71
	3	3374.1	2745.26	136.58	45.30	1.94
	Avg	3133.5	2580.22	127.95	42.44	1.82
2100/2	1	1394.5	1069.18	104.82	227.49	1.49
	2	1695.0	1312.48	132.57	312.50	1.88
	3	1605.5	1224.63	120.06	260.56	1.70
	Avg	1565.0	1202.10	119.15	266.85	1.69

TABLE D-35. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CATERPILLAR 3406 DI-33° TIMING (RUN 1)
(13-MODE FTP WEIGHTING FACTORS)

Engine rpm	% Load	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Weighted Power kW	Weighted Fuel kg/hr	Weighted Part. g/hr	Weighted $SO_4^=$ mg/hr
Idle	---	-----	2.1	11.51	697.25	0.067	-----	0.14	0.77	46.71
1260	2	3.8	4.7	18.83	901.88	0.08	0.30	0.38	1.51	72.15
	25	46.7	13.2	23.26	1693.22	0.08	3.74	1.06	1.86	135.46
	50	93.3	22.3	29.01	3995.20	0.08	7.46	1.78	2.32	319.62
	75	141.9	32.8	32.84	3327.95	0.08	11.35	2.62	2.63	266.24
	100	186.4	43.7	63.37	4516.57	0.08	14.91	3.50	5.07	361.33
Idle	---	-----	2.1	11.51	697.25	0.067	-----	0.14	0.77	46.71
2100	100	244.1	56.8	67.21	7013.00	0.08	19.53	4.54	5.38	561.04
	75	182.3	44.0	35.33	5447.43	0.08	14.58	3.52	2.83	435.79
	50	122.8	32.3	29.99	4045.38	0.08	9.82	2.58	2.40	323.63
	25	61.2	20.3	22.76	2570.30	0.08	4.90	1.62	1.82	205.62
	2	4.7	10.2	25.71	1069.18	0.08	0.38	0.82	2.06	85.53
Idle	---	-----	2.1	11.51	697.25	0.067	-----	0.14	0.77	46.71
							86.97	22.84	30.19	2906.54

Brake Specific Particulate, g/kW-hr 0.347
Fuel Specific Particulate, g/kg fuel 1.322

Brake Specific $SO_4^=$, mg/kW-hr 33.42
Fuel Specific $SO_4^=$, mg/kg fuel 127.26

TABLE D-36. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CATERPILLAR 3406 DI-33° TIMING (RUN 2)
(13-MODE FTP WEIGHTING FACTORS)

Engine rpm	% Load	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Weighted Power kW	Weighted Fuel kg/hr	Weighted Part. g/hr	Weighted $SO_4^=$ mg/hr
Idle	---	-----	----	12.59	872.64	0.067	-----	0.15	0.84	58.47
1260	2	3.8	2.3	24.67	1277.99	0.08	0.30	0.44	1.97	102.23
	25	46.9	5.5	26.07	1992.24	0.08	3.75	1.08	2.09	159.38
	50	93.6	13.5	29.68	3621.28	0.08	7.49	1.79	2.37	289.70
	75	140.6	22.4	38.47	4184.62	0.08	11.25	2.56	3.08	334.77
	100	188.3	32.0	65.46	5240.90	0.08	15.06	3.50	5.24	419.27
Idle	---	-----	43.7	12.59	872.64	0.067	-----	0.15	0.84	58.47
2100	100	246.0	2.3	58.05	6777.53	0.08	19.68	4.58	4.64	542.20
	75	184.4	57.2	44.98	5103.80	0.08	14.75	3.55	3.60	408.30
	50	121.6	44.4	29.54	4262.19	0.08	9.73	2.54	2.36	340.98
	25	60.6	31.8	20.71	2425.11	0.08	4.85	1.61	1.66	194.01
	2	4.2	20.1	24.40	1312.48	0.08	0.34	0.79	1.95	105.0
Idle	---	-----	9.9	12.59	872.64	0.067	-----	0.15	0.84	58.47
			2.1				87.2	22.89	31.48	3071.25

Brake Specific Particulate, g/kW-hr 0.361
Fuel Specific Particulate, g/kg fuel 1.375

Brake Specific $SO_4^=$, mg/kW-hr 35.22
Fuel Specific $SO_4^=$, mg/kg fuel 134.17

TABLE D-37. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CATERPILLAR 3406 DI-33° TIMING (RUN 3)
(13-MODE FTP WEIGHTING FACTORS)

Engine rpm	% Load	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Weighted Power kW	Weighted Fuel kg/hr	Weighted Part. g/hr	Weighted $SO_4^=$ mg/hr
Idle	---	-----	2.2	13.73	888.34	0.067	-----	0.15	0.92	59.52
1260	2	3.8	4.9	23.55	1212.44	0.08	0.30	0.39	1.88	97.00
	25	46.7	13.1	24.78	1821.93	0.08	3.74	1.05	1.98	145.75
	50	93.4	22.3	30.29	3771.05	0.08	7.47	1.78	2.42	301.68
	75	140.5	32.4	40.73	4027.59	0.08	11.24	2.59	3.26	322.21
	100	185.9	43.5	76.26	4714.03	0.08	14.87	3.48	6.10	377.12
Idle	---	-----	2.2	13.73	888.34	0.067	-----	0.15	0.92	59.52
2100	100	241.5	56.3	63.69	7231.83	0.08	19.32	4.50	5.10	578.55
	75	184.4	44.4	39.58	4370.08	0.08	14.75	3.55	3.17	349.61
	50	121.3	31.9	29.98	4152.15	0.08	9.70	2.55	2.39	332.17
	25	60.6	20.1	19.30	2745.26	0.08	4.85	1.61	1.54	219.62
	2	4.7	10.3	21.76	1224.63	0.08	0.38	0.82	1.74	97.97
Idle	---	-----	2.2	13.73	888.34	0.067	-----	0.15	0.92	59.52
							86.62	22.77	32.34	3000.24

Brake Specific Particulate, g/kW-hr 0.373
Fuel Specific Particulate, g/kg fuel 1.420

Brake Specific $SO_4^=$, mg/kW-hr 34.64
Fuel Specific $SO_4^=$, mg/kg fuel 131.76

Brake Specific $SO_4^=$, mg/kW-hr 34.64
Fuel Specific $SO_4^=$, mg/kg fuel 131.76

TABLE D-38. SUMMARY OF EXHAUST PARTICULATE FROM CATERPILLAR 3406 IDI ENGINE

(Based on 47 mm Glassfiber Filters)

Engine rpm/% load	Run	Concentration mg/m^3	Particulate Rate		
			g/hr	g/kg fuel	g/kw-hr
1400/2	1	22.57	11.54	1.96	3.04
	2	23.09	11.73	2.06	3.09
	Avg	22.83	11.64	2.01	3.07
1400/25	1	21.31	11.23	0.84	0.23
	2	21.35	11.28	0.84	0.23
	Avg	21.33	11.26	0.84	0.23
1400/50	1	31.14	19.37	0.83	0.20
	2	34.32	21.26	0.91	0.22
	Avg	32.73	20.32	0.87	0.21
1400/75	1	81.57	62.63	1.79	0.43
	2	79.72	60.74	1.73	0.41
	Avg	80.65	61.69	1.76	0.42
1400/100	1	109.38	101.49	2.06	0.50
	2	123.06	113.89	2.31	0.57
	Avg	116.22	107.69	2.19	0.54
Idle	1	20.83	4.65	2.91	----
	2	17.85	3.99	2.49	----
	Avg	19.34	4.32	2.70	----
2100/100	1	37.34	46.45	0.75	0.19
	2	38.00	47.30	0.77	0.20
	Avg	37.64	46.88	0.76	0.20
2100/75	1	51.25	53.50	1.16	0.30
	2	46.77	50.08	1.05	0.27
	Avg	49.01	51.79	1.11	0.29
2100/50	1	35.92	31.32	0.97	0.26
	2	37.72	32.61	1.01	0.26
	Avg	36.82	31.97	0.99	0.26
2100/25	1	40.67	29.91	1.50	0.50
	2	47.52	35.05	1.73	0.56
	Avg	44.10	32.48	1.62	0.53
2100/2	1	32.44	22.49	2.16	4.79
	2	34.86	24.18	2.35	5.14
	Avg	33.65	23.34	2.26	4.97

TABLE D-39. SUMMARY OF EXHAUST $SO_4^=$ FROM CATERPILLAR 3406 IDI ENGINE (BASED ON 47 mm FLUOROPORE FILTERS)

Engine rpm/% load	Run No.	Concentration µg/m^3	Sulfate Rate mg/hr	Sulfate Rate mg/kg fuel	Sulfate Rate mg/kW-hr	$SO_4^=$ as % Fuel S
1400/2	1	1020.8	521.9	88.5	137.3	1.25
	2	985.8	500.8	87.9	131.8	1.25
	Avg	1003.3	511.4	88.2	134.6	1.25
1400/25	1	2667.1	1404.8	104.8	28.6	1.49
	2	2286.0	1207.6	90.1	24.6	1.28
	Avg	2476.6	1306.2	97.5	26.6	1.39
1400/50	1	4880.0	3034.3	129.7	30.9	1.84
	2	5685.0	3521.8	151.2	35.9	2.14
	Avg	5282.5	3278.1	140.5	33.4	2.04
1400/75	1	7547.2	5794.4	165.5	39.4	2.35
	2	5857.1	4462.9	127.1	30.3	1.80
	Avg	6702.2	5128.7	146.4	34.9	2.08
1400/100	1	5904.2	5478.4	111.1	27.2	1.58
	2	5965.3	5520.6	112.2	27.5	1.59
	Avg	5934.8	5499.5	111.7	27.4	1.59
Idle	1	1012.2	226.0	141.3	----	2.00
	2	1081.8	254.2	141.2	----	2.00
	Avg	1047.0	240.1	141.3	----	2.00
2100/100	1	6210.8	7726.4	126.2	32.3	1.75
	2	6473.1	8061.3	131.3	33.6	1.82
	Avg	6342.0	7893.9	128.8	33.0	1.79
2100/75	1	9258.1	9664.1	210.1	53.7	2.91
	2	9376.9	9933.4	209.1	53.1	2.90
	Avg	9267.5	9798.8	209.6	53.4	2.91
2100/50	1	3726.6	3221.5	99.7	25.9	1.41
	2	4376.2	3790.8	117.4	30.5	1.66
	Avg	4051.4	3506.2	108.6	28.2	1.54
2100/25	1	5471.7	4023.3	202.2	67.1	2.80
	2	5202.6	3838.4	189.1	61.8	2.62
	Avg	5310.2	3930.9	195.7	64.5	2.71
2100/2	1	5497.1	3812.8	370.2	811.2	5.25
	2	4683.0	3265.2	311.0	694.7	4.31
	Avg	5090.1	3539.0	340.6	753.0	4.78

TABLE D-40. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CATERPILLAR 3406 IDI ENGINE RUN 1
(13-MODE FTP WEIGHTING FACTORS)

						Weighted			
Engine rpm/% load	Power kW	Fuel kg/hr	Particulate g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr
Idle	---	1.6	4.65	226.0	0.067	---	0.11	0.31	15.14
1400/2	3.8	5.9	11.54	521.9	0.08	0.30	0.47	0.92	41.75
1400/25	49.1	13.4	11.23	1404.8	0.08	3.93	1.07	0.90	112.38
1400/50	98.1	23.4	19.37	3034.3	0.08	7.85	1.87	1.55	342.74
1400/75	147.2	35.0	62.63	5794.4	0.08	11.78	2.80	5.01	463.55
1400/100	201.2	49.3	101.49	5478.4	0.08	16.10	3.94	8.12	438.27
Idle	---	1.6	4.65	226.0	0.067	---	0.11	0.31	15.14
2100/100	243.8	62.3	46.45	7726.4	0.08	19.50	4.98	3.72	618.11
2100/75	180.1	46.0	53.5	9664.1	0.08	14.41	3.68	4.28	733.13
2100/50	122.1	32.2	31.32	3221.5	0.08	9.77	2.58	2.51	257.72
2100/25	60.0	19.9	29.91	4023.3	0.08	4.80	1.59	2.39	321.86
2100/2	4.7	10.4	22.49	3812.8	0.08	0.38	0.83	1.80	305.02
Idle	---	1.6	4.65	226.0	0.067	---	0.11	0.31	15.14
						88.82	24.14	32.13	3719.95

Brake Specific Particulate g/kW-hr	0.362	Brake Specific $SO_4^=$, mg/kW-hr	41.88
Fuel Specific Particulate, g/kg fuel	1.331	Fuel Specific $SO_4^=$, mg/kg fuel	154.10

TABLE D-41. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
CATERPILLAR 3406 IDI ENGINE RUN 2
(13-MODE FTP WEIGHTING FACTORS)

						Weighted			
Engine rpm/% load	Power kW	Fuel kg/hr	Particulate g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr
Idle	---	1.6	3.99	254.2	0.067	---	0.11	0.27	17.03
1400/2	3.8	5.7	11.73	500.8	0.08	0.30	0.46	0.94	40.06
1400/25	49.1	13.4	11.28	1207.6	0.08	3.93	1.07	0.90	96.61
1400/50	98.1	23.3	21.26	3521.8	0.08	7.85	1.86	1.70	281.74
1400/75	147.2	35.1	60.74	4462.9	0.08	11.78	2.81	4.86	357.03
1400/100	200.6	49.2	113.89	5520.9	0.08	16.05	3.94	9.11	441.65
Idle	---	1.6	3.99	254.2	0.067	---	0.11	0.27	17.03
2100/100	240.5	61.3	47.30	8061.3	0.08	19.24	4.90	3.78	644.90
2100/75	186.9	47.5	50.08	9933.4	0.08	14.95	3.80	4.01	794.67
2100/50	124.2	32.3	32.61	3790.8	0.08	9.94	2.58	2.61	303.26
2100/25	62.1	20.3	35.05	3838.4	0.08	4.97	1.62	2.80	307.07
2100/2	4.7	10.3	24.18	3265.2	0.08	0.38	0.82	1.93	261.22
Idle	---	1.6	3.99	254.2	0.067	---	0.11	0.27	17.03
						89.39	24.19	33.45	3579.30

Brake Specific Particulate, g/kW-hr	0.374	Brake Specific $SO_4^=$, mg/kW-hr	40.04
Fuel Specific Particulate, g/kg fuel	1.383	Fuel Specific $SO_4^=$, mg/kg fuel	147.97

TABLE D-42. SUMMARY OF PARTICULATE, BaP AND ORGANIC SOLUBLES FROM 8 X 10 SIZE GLASS FILTER SAMPLES CATERPILLAR 3406

Condition	Engine	Particulate Rate				BaP				Organic
rpm[1]/load %	Configuration	mg/m^3	g/hr	g/kg fuel	g/kW-hr	μg/m^3	μg/hr	μg/kg fuel	μg/kW-hr	Solubles, %
1260/2	DI 28°	36.71	17.80	4.05	4.34	0.062	29.94	6.80	7.30	4.87
	DI 28°/EGR	35.15	7.69	1.75	1.88	0.101	21.99	5.00	5.36	18.08
	DI 18°	37.37	18.01	3.92	4.09	0.246	118.37	25.73	26.90	38.48
	DI 33°	36.91	18.04	3.84	4.75	0.243	118.93	25.30	31.30	9.29
	IDI 10°	23.95	11.99	2.14	3.16	0.039	19.38	3.52	5.10	12.94
1260/50	DI 28°	59.27	34.41	1.54	0.35	0.007	4.04	0.18	0.04	23.88
	DI 28°/EGR	156.88	69.90	3.05	0.72	-----	----	----	----	16.99
	DI 18°	176.47	97.75	4.27	1.00	-----	----	----	----	23.90
	DI 33°	39.82	22.93	1.01	0.24	0.059	34.10	1.51	0.36	14.70
	IDI 10°	31.57	19.34	0.83	0.20	-----	----	----	----	4.53
1260/100	DI 28°	132.44	101.51	2.33	0.53	-----	----	----	----	30.06
	DI 28°/EGR	157.08	115.46	2.62	0.60	-----	----	----	----	13.19
	DI 18°	333.37	257.17	5.88	1.41	-----	----	----	----	0.59
	DI 33°	72.79	56.25	1.30	0.30	-----	----	----	----	1.51
	IDI 10°	107.24	99.14	2.02	0.50	-----	----	----	----	5.09
Idle	DI 28°	29.66	8.09	5.06	----	0.126	34.29	21.43	----	31.02
	DI 28°/EGR	44.03	6.54	3.27	----	0.041	6.09	3.05	----	27.70
	DI 18°	23.25	6.62	3.48	----	0.321	91.44	48.13	----	6.52
	DI 33°	51.10	14.35	6.83	----	1.348	378.78	180.37	----	8.28
	IDI 10°	18.71	4.26	2.51	----	0.055	12.58	7.40	----	9.88
2100/100	DI 28°	95.68	116.15	2.03	0.48	-----	----	----	----	21.36
	DI 28°/EGR	189.15	196.63	3.46	0.84	-----	----	----	----	23.97
	DI 18°	189.07	236.89	4.13	1.06	-----	----	----	----	22.64
	DI 33°	42.20	50.22	0.88	0.21	-----	----	----	----	8.28
	IDI 10°	30.53	37.53	0.62	0.16	-----	----	----	----	0.84
2100/50	DI 28°	66.54	61.27	1.98	0.51	-----	----	----	----	2.96
	DI 28°/EGR	198.16	136.49	4.05	1.07	-----	----	----	----	22.15
	DI 18°	166.24	115.84	4.98	1.36	0.049	45.74	1.46	0.04	27.59
	DI 33°	29.53	27.41	0.85	0.22	-----	----	----	----	17.55
	IDI 10°	32.91	28.37	0.88	0.23	-----	----	----	----	11.66
2100/2	DI 28°	37.63	28.58	2.98	6.08	0.069	52.16	5.43	11.10	5.08
	DI 28°/EGR	81.07	28.45	2.93	5.47	0.130	45.17	4.71	8.79	8.76
	DI 18°	68.36	51.33	5.18	12.22	0.198	148.53	15.00	35.36	19.44
	DI 33°	30.27	23.41	2.30	5.57	0.152	117.74	11.54	28.03	31.39
	IDI 10°	31.23	22.21	2.12	4.73	0.092	65.69	6.26	13.98	35.88

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(1) IDI speed was 1400 rpm instead of 1260 rpm for DI version

TABLE D-43. BRAKE AND FUEL SPECIFIC BaP RATE - 7-MODE CYCLE
CATERPILLAR 3406 DI, 28° BTC TIMING

Mode	Engine rpm	Engine load, %	Power kW	Fuel kg/hr	BaP µg/hr	Org. Sol., %	Wgt. Fact.	Power kW	Fuel kg/hr	BaP µg/hr	Org. Sol., %
							W.F. Derived From 13-Mode FTP				
1	1260	2	4.1	4.4	29.94	4.87	0.12	0.49	0.53	3.59	0.58
2	1260	50	98.0	22.4	4.04	23.88	0.16	15.68	3.58	0.65	3.82
3	1260	100	192.5	43.5	-----	30.06	0.12	23.10	5.22	----	3.61
4	Idle		-----	1.6	34.29	31.02	0.20	-----	0.32	6.86	6.20
5	2100	100	243.3	57.1	-----	21.36	0.12	29.20	6.85	----	2.56
6	2100	50	120.1	31.0	-----	2.96	0.16	19.22	4.96	----	0.47
7	2100	2	4.7	9.6	52.16	5.08	0.12	0.56	1.15	6.26	0.61
								88.25	22.61	17.36	17.85

Brake Specific BaP, µg/kW-hr	0.197
Fuel Specific BaP, µg/kg fuel	0.768
Cycle Specific Organic Solubles, %	17.85

Wgt. Fact.	Power kW	Fuel kg/hr	BaP µg/hr	Org. Sol., %
W.F. Derived from 21-Mode EPA				
0.225	0.92	0.99	6.74	1.10
0.092	9.02	2.06	0.37	2.20
0.049	9.43	2.13	----	1.47
0.269	----	0.43	9.22	8.34
0.176	42.82	10.05	----	3.76
0.110	13.21	3.41	----	0.33
0.079	0.37	0.76	4.12	0.40
	75.77	19.83	20.45	17.60

Brake Specific BaP, µg/kW-hr	0.270
Fuel Specific BaP, µg/kg fuel	1.031
Cycle Specific Organic Solubles, %	17.60

TABLE D-44. BRAKE AND FUEL SPECIFIC BaP RATE - 7-MODE CYCLE
CATERPILLAR 3406 DI, 28° BTC TIMING, WITH EGR

Mode	Engine rpm	Engine load, %	Power kW	Fuel kg/hr	BaP µg/hr	Org. Sol., %	Wgt. Fact.	Power kW	Fuel kg/hr	BaP µg/hr	Org. Sol., %
							W.F. Derived from 13-Mode FTP				
1	1260	2	4.1	4.4	21.99	18.08	0.12	0.49	0.53	2.64	2.17
2	1260	50	97.4	22.9	-----	16.99	0.16	15.58	3.66	----	2.72
3	1260	100	192.3	44.0	-----	13.19	0.12	23.08	5.28	----	1.58
4	Idle		-----	2.0	6.09	27.70	0.20	-----	0.40	1.22	5.54
5	2100	100	233.3	56.9	-----	23.97	0.12	28.00	6.83	----	2.88
6	2100	50	127.9	33.7	-----	22.15	0.12	20.46	5.39	----	3.54
7	2100	2	5.2	9.7	45.17	8.76	0.16	0.62	1.16	5.42	1.05
							0.12	88.23	23.25	9.28	19.48

Brake Specific BaP, µg/kW-hr 0.105
Fuel Specific BaP, µg/kg fuel 0.399
Cycle Specific Organic Solubles, % 19.48

W.F. Derived from 13-Mode FTP

Wgt. Fact.	Power kW	Fuel kg/hr	BaP µg/hr	Org. Sol., %
0.225	0.92	0.99	4.95	4.07
0.092	8.96	2.11	----	1.56
0.049	9.42	2.16	----	0.65
0.269	----	0.54	1.64	7.45
0.176	41.06	10.01	----	4.22
0.110	14.07	3.71	----	2.44
0.079	0.41	0.77	3.57	0.69
	74.84	20.29	10.16	21.08

Brake Specific BaP µg/kW-hr 0.136
Fuel Specific BaP, µg/kg fuel 0.501
Cycle Specific Organic Solubles, % 21.08

TABLE D-45. BRAKE AND FUEL SPECIFIC BaP RATE - 7-MODE CYCLE
CATERPILLAR 3406 DI, 18° BTC TIMING

Mode	Engine rpm	Engine load, %	Power kW	Fuel kg/hr	BaP µg/hr	Org. Sol., %	Wgt. Fact.	Power kW	Fuel kg/hr	BaP µg/hr	Org. Sol., %
							W.F. Derived from 13-Mode FTP				
1	1260	2	4.4	4.6	118.37	38.48	0.12	0.53	0.55	14.20	4.50
2	1260	50	97.7	22.9	-----	23.90	0.16	15.63	9.66	-----	3.82
3	1260	100	182.3	43.7	-----	0.59	0.12	21.88	5.24	-----	0.07
4	Idle		-----	1.9	91.34	6.52	0.20	-----	0.38	18.29	1.30
5	2100	100	222.6	57.3	-----	22.64	0.12	26.71	6.88	-----	2.72
6	2100	50	114.3	31.3	45.74	27.59	0.16	18.29	5.01	7.32	4.41
7	2100	2	4.2	9.9	148.53	19.44	0.12	0.50	1.19	17.82	2.33
								83.54	28.91	57.63	19.15

Brake Specific BaP, µg/kW-hr	0.690
Fuel Specific BaP, µg/kg fuel	1.993
Cycle Specific Organic Solubles, %	19.15

Wgt. Fact.	Power kW	Fuel kg/hr	BaP µg/hr	Org. Sol., %
W.F. Derived from 21-Mode EPA				
0.225	0.99	1.04	26.63	8.66
0.092	8.99	2.11	-----	2.20
0.049	8.93	4.02	-----	0.03
0.269	----	0.51	24.60	1.75
0.176	39.18	10.08	-----	3.98
0.110	12.57	3.44	5.03	3.03
0.079	0.33	0.78	11.73	1.54
	70.99	21.98	67.99	21.19

Brake Specific BaP, µg/kW-hr	0.958
Fuel Specific BaP, µg/kg fuel	3.093
Cycle Specific Organic Solubles, %	21.19

TABLE D-46. BRAKE AND FUEL SPECIFIC BaP RATE - 7-MODE CYCLE
CATERPILLAR 3406 DI, 33° BTC TIMING

Mode	Engine rpm	Engine load, %	Power kW	Fuel kg/hr	BaP μg/hr	Org. Sol., %	Wgt. Fact.	Power kW	Fuel kg/hr	BaP μg/hr	Org. Sol., %
							W.F. Derived from 13-Mode FTP				
1	1260	2	3.8	4.7	118.93	9.29	0.12	0.46	0.56	14.27	1.11
2	1260	50	94.6	22.6	34.10	14.70	0.16	15.14	3.62	5.46	2.35
3	1260	100	184.5	43.4	-----	1.51	0.12	22.14	5.21	-----	0.18
4	Idle		-----	2.1	378.78	8.28	0.20	-----	0.42	75.76	1.66
5	2100	100	244.0	56.8	-----	8.28	0.12	29.28	6.82	-----	0.99
6	2100	50	123.7	32.1	-----	17.55	0.16	19.79	5.14	-----	2.81
7	2100	2	4.2	10.2	117.74	31.39	0.12	0.50	1.22	14.13	3.77
								87.31	22.99	109.62	12.87
Brake Specific BaP, μg/kW-hr				1.256							
Fuel Specific BaP, μg/kg fuel				4.768							
Cycle Specific Organic Solubles, %				12.87							
							W.F. Derived from 21-Mode EPA				
							0.225	0.86	1.06	26.74	2.09
							0.092	8.70	2.08	3.14	1.35
							0.049	9.04	2.13	-----	0.07
							0.269	----	0.56	101.89	2.23
							0.176	42.94	10.00	-----	1.46
							0.110	13.61	3.53	-----	1.93
							0.079	0.33	0.81	9.30	2.48
								75.48	20.17	141.07	11.61
Brake Specific BaP, μg/kW-hr				1.869							
Fuel Specific BaP, μg/kg fuel				6.994							
Cycle Specific Organic Solubles, %				11.61							

TABLE D-47. BRAKE AND FUEL SPECIFIC BaP RATE - 7-MODE CYCLE
CATERPILLAR 3406 IDI ENGINE

Mode	Engine rpm	Engine load, %	Power kw	Fuel kg/hr	BaP µg/hr	Org. Sol., %	Wgt. Fact.	Power kw	Fuel kg/hr	BaP µg/hr	Org. Sol., %
							W.F. Derived From 13-Mode FTP				
1	1400	2	3.8	5.5	19.38	12.94	0.12	0.46	0.66	2.33	1.55
2	1400	50	98.5	23.3	BMD	4.53	0.16	15.76	3.73	----	0.72
3	1400	100	199.6	49.1	BMD	5.09	0.12	23.95	5.89	----	0.61
4	Idle	---	-----	1.7	12.58	9.88	0.20	-----	0.34	2.52	1.98
5	1900	100	238.0	60.5	BMD	0.84	0.12	28.56	7.26	----	0.10
6	1900	50	122.1	32.2	BMD	11.66	0.16	19.54	5.15	----	1.87
7	1900	2	4.7	10.5	65.69	35.88	0.12	0.56	1.26	7.88	4.31
								88.83	24.29	12.73	11.14

Brake Specific Bap, µg/kw-hr	0.143
Fuel Specific BaP, µg/kg fuel	0.524
Cycle Specific Organic Solubles, %	11.14

W.F. Derived From 21-Mode EPA

Wgt. Fact.	Power kw	Fuel kg/hr	BaP µg/hr	Org. Sol., %
0.225	0.86	1.24	4.36	2.91
0.092	9.06	2.14	----	0.42
0.049	9.78	2.41	----	0.25
0.269	-----	0.46	3.38	2.66
0.176	41.89	10.65	----	0.15
0.110	13.43	3.54	----	1.28
0.079	0.37	0.83	5.19	2.83
	75.39	21.27	12.93	10.50

Brake Specific BaP, µg/kw-hr	0.172
Fuel Specific BaP, µg/kg fuel	0.608
Cycle Specific Organic Solubles, %	10.50

BMD - Below Minimum Detectable

TABLE D-48. METALS ANALYSIS OF FILTER COLLECTED PARTICULATE
(PERCENT BY WEIGHT BASED ON FLUOROPORE FILTER SAMPLES)

Condition Speed/ % Load	Configuration	Al	Si	P	S	Cl	K	Ca	Fe	Cu
Inter/02	DI 28°				1.86	0.12		0.09		
	DI 28°/EGR			0.25	4.41	0.07		0.21		
	DI 18°				1.9			0.09		
	DI 33°			1.51				0.04		
	IDI 10°				2.09			0.10		
Inter/25	DI 28°			0.12	4.7	0.10		0.12		
	DI 28°/EGR			0.03	1.16	0.03		0.02		
	DI 18°				1.8			0.05		
	DI 33°				3.97			0.09		
	IDI 10°			0.13	5.96			0.17		
Inter/50	DI 28°			0.08	6.2	0.10		0.12		
	DI 28°/EGR			0.02	0.81	0.02		0.02		
	DI 18°				2.0	0.02		0.03	0.26	
	DI 33°			0.08	6.34			0.12		
	IDI 10°			0.06	6.7	0.07		0.09		
Inter/75	DI 28°			0.05	2.87	0.12		0.07		
	DI 28°/EGR		0.01	0.01	0.58	0.04		0.02		
	DI 18°				1.2	0.03	0.01	0.05		
	DI 33°			0.10	6.41	0.01		0.14		
	IDI 10°				2.9	0.10		0.03		
Inter/100	DI 28°	0.01	0.02	0.02	1.67	0.05		0.05		
	DI 28°/EGR			0.04	0.91	0.05		0.05		
	DI 18°				0.19			0.01		
	DI 33°				3.85	0.03		0.09		
	IDI 10°			0.02	2.0	0.04		0.06		
Idle	DI 28°				2.81	0.03		0.05		
	DI 28°/EGR			0.18	4.13			0.09		
	DI 18°		0.08	0.12	11.6	0.60		0.40		
	DI 33°				1.56			0.02		
	IDI 10°				3.06					
High/100	DI 28°			0.08	2.72	0.06		0.19		
	DI 28°/EGR			0.05	1.22	0.03		0.06		
	DI 18°			0.02	1.6	0.03		0.05	0.05	
	DI 33°			0.15	6.1	0.04		0.32	0.22	
	IDI 10°			0.21	7.2			0.59		
High/75	DI 28°			0.05	2.90	0.11		0.12		
	DI 28°/EGR			0.02	1.08	0.02		0.04		
	DI 18°	0.004			1.4	0.02		0.03		
	DI 33°			0.12	4.1			0.18		
	IDI 10°			0.13	7.5			0.28		0.23
High/50	DI 28°			0.05	2.88	0.04		0.08		
	DI 28°/EGR			0.05	1.60	0.02		0.06		
	DI 18°			0.01	1.4	0.01		0.04		
	DI 33°			0.10	8.15			0.17		
	IDI 10°			0.05	4.4			0.12		
High/25	DI 28°			0.07	2.44	0.05		0.09		
	DI 28°/EGR			0.03	0.91	0.01		0.03		
	DI 18°									
	DI 33°			0.16	8.2			0.22	0.41	
	IDI 10°			0.09	5.4			0.11		0.10
High/02	DI 28°			0.12	2.24	0.05		0.15		
	DI 28°/EGR			0.06	1.65	0.02		0.10		
	DI 18°				1.2	0.02		0.06		
	DI 33°			0.08	3.4			0.14		
	IDI 10°			0.06	5.6	0.11		0.09		

TABLE D-49. PERCENT PER STAGE OF TOTAL PARTICULATE COLLECTED BY ANDERSON IMPACTOR FOR CATERPILLAR 3406

Stage No.	ECD, micron	1260 rpm				2100 rpm		
		2%	50%	100%	Idle	100%	50%	2%
Direct Injection 28°BTC Timing								
1	10.9	1.2	0.93	0.73	0.22	0.69	0.28	0.22
2	6.8	0.68	1.2	0.63	0.38	0.86	0.24	0.37
3	4.6	1.3	1.3	0.75	0.59	1.6	0.24	0.51
4	3.2	2.2	1.8	1.1	1.0	1.0	0.56	1.3
5	2.0	3.7	2.0	2.5	1.3	1.7	0.76	1.5
6	1.03	2.0	2.7	4.3	0.81	3.2	2.5	1.9
7	0.63	3.1	3.1	7.3	1.9	4.3	3.2	1.3
8	0.42	3.1	3.8	7.8	3.7	5.3	2.4	2.2
Filter	<0.42	82.7	83.1	74.9	90.1	81.4	89.8	90.7
Direct Injection 28°BTC EGR								
1	10.9	0.18	0.19	0.17	0.36	0.32	0.09	0.12
2	6.8	0.13	0.19	0.09	0.43	0.58	0.31	0.15
3	4.6	0.24	0.42	0.65	0.58	0.63	0.43	0.31
4	3.2	0.18	0.94	0.96	1.2	1.1	0.95	0.54
5	2.0	0.48	2.4	1.7	1.0	2.6	1.4	0.81
6	1.03	1.4	2.1	2.9	1.4	3.8	2.6	1.5
7	0.63	1.8	3.0	6.0	2.7	3.9	3.1	1.3
8	0.42	5.5	3.5	8.9	3.9	2.7	3.7	1.3
Filter	<0.42	90.1	87.3	78.7	88.4	84.3	87.5	94.0
Direct Injection 18°BTC 10° Retarded								
1	10.9	1.4	0.19	0.41	0.47	0.26	0.34	0.35
2	6.8	0.28	0.15	0.64	0.79	0.31	0.55	0.54
3	4.6	1.0	0.39	1.1	0.63	0.78	0.59	0.52
4	3.2	0.76	0.62	1.2	0.95	1.1	0.59	1.1
5	2.0	0.71	1.8	2.1	1.3	2.4	1.9	1.2
6	1.03	2.2	2.2	2.9	1.1	3.2	2.8	2.1
7	0.63	4.4	2.8	4.5	1.7	3.9	2.5	3.0
8	0.42	5.2	2.7	5.9	2.4	3.8	3.6	2.7
Filter	<0.42	84.1	89.1	81.2	90.7	84.2	87.0	88.5
Direct Injection 33°BTC 5° Advanced								
1	10.9	0.84	0.60	0.51	0.69	0.45	0.35	0.70
2	6.8	1.4	1.1	0.54	0.57	0.63	0.74	0.60
3	4.6	0.78	1.5	1.1	0.82	0.79	0.74	0.38
4	3.2	0.84	2.2	1.0	0.28	0.67	1.2	0.35
5	2.0	1.4	3.6	1.9	0.92	1.8	0.79	0.77
6	1.03	1.2	5.3	4.2	1.2	3.1	3.0	0.70
7	0.63	1.5	4.2	7.3	1.9	4.1	1.6	0.70
8	0.42	6.2	4.2	8.7	6.4	4.4	2.0	0.66
Filter	<0.42	85.8	77.3	74.8	87.3	84.1	89.6	95.1
Indirect Injection 10°BTC Prechamber								
1	10.9	1.0	0.13	0.40	0.52	0.45	0.52	0.25
2	6.8	1.2	1.1	0.34	1.0	0.34	0.74	0.18
3	4.6	1.3	0.81	1.0	0.98	0.52	0.86	0.74
4	3.2	1.2	0.86	0.77	2.7	0.76	1.1	1.3
5	2.0	2.3	1.2	1.8	2.7	1.6	1.3	1.1
6	1.03	2.6	2.7	4.0	1.6	2.7	2.0	2.2
7	0.63	2.5	3.6	5.0	3.2	2.6	2.6	2.2
8	0.42	3.1	4.3	6.7	1.4	2.5	3.5	2.7
Filter	<0.42	84.8	85.4	80.1	85.8	88.6	87.4	89.3

TABLE D-50. ALDEHYDES BY DNPH FOR CATERPILLAR 3406, 28° BTC

		1260 rpm				2100 rpm		
Aldehyde	Rate	2	50	100	Idle	100	50	2
Form-aldehyde	$\mu g/m^3$	1626	2639	1933	4693	2816	1608	2546
	mg/hr	1053	2002	1923	1637	4408	2030	2611
	mg/kg fuel	234	90	44	779	76	61	251
	mg/kW-hr	277	21	10	---	18	16	622
Acet-aldehyde	$\mu g/m^3$	252	---	---	1406	---	---	151
	mg/hr	353	---	---	1060	---	---	335
	mg/kg fuel	78	---	---	505	---	---	32
	mg/kW-hr	93	---	---	---	---	---	80
Acetone	$\mu g/m^3$	---	---	126	624	---	---	---
	mg/hr	---	---	465	808	---	---	---
	mg/kg fuel	---	---	11	385	---	---	---
	mg/kW-hr	---	---	2	---	---	---	---
Iso-butanal	$\mu g/m^3$	559	163	283	660	210	221	473
	mg/hr	2080	710	1620	1322	1885	1605	2790
	mg/kg fuel	462	32	37	630	32	48	268
	mg/kW-hr	547	7	9	---	8	13	664
Crotonal	$\mu g/m^3$	421	262	452	916	294	405	508
	mg/hr	1489	1085	2459	1747	3462	2792	2846
	mg/kg fuel	331	49	57	832	60	83	274
	mg/kW-hr	392	11	13	---	14	23	678
Hexanal	$\mu g/m^3$	56	---	75	145	---	56	92
	mg/hr	401	---	832	562	---	782	1048
	mg/kg fuel	89	---	19	267	---	23	101
	mg/kW-hr	106	---	4	---	---	6	250
Benz-aldehyde	$\mu g/m^3$	27	---	427	187	40	113	4
	mg/hr	217	---	5291	813	771	1782	47
	mg/kg fuel	48	---	122	387	13	53	5
	mg/kW-hr	57	---	28	---	3	14	11

TABLE D-51. ALDEHYDES BY DNPH FOR CATERPILLAR 3406, 28° BTC WITH EGR

		1260 rpm				2100 rpm		
Aldehyde	Rate	2	50	100	Idle	100	50	2
Form-aldehyde	$\mu g/m^3$	1357	1440	1765	3708	1394	2927	2630
	mg/hr	387	869	1683	658	1318	4063	1206
	mg/kg fuel	88	38	39	337	23	123	127
	mg/kW-hr	102	9	9	---	6	32	232
Acet-aldehyde	$\mu g/m^3$	460	---	---	---	---	---	221
	mg/hr	284	---	---	---	---	---	219
	mg/kg fuel	64	---	---	---	---	---	23
	mg/kW-hr	75	---	---	---	---	---	42
Acetone	$\mu g/m^3$	39	---	---	---	---	---	---
	mg/hr	41	---	---	---	---	---	---
	mg/kg fuel	9	---	---	---	---	---	---
	mg/kW-hr	11	---	---	---	---	---	---
Iso-butanal	$\mu g/m^3$	299	621	213	458	310	481	442
	mg/hr	490	2153	1169	467	1687	3813	1166
	mg/kg fuel	111	94	27	239	29	116	122
	mg/kW-hr	129	22	6	---	7	31	224
Crotonal	$\mu g/m^3$	877	1143	472	1297	857	909	1547
	mg/hr	1366	3768	2459	1259	4429	6846	3879
	mg/kg fuel	310	164	57	645	77	208	407
	mg/kW-hr	360	39	13	---	19	55	746
Hexanal	$\mu g/m^3$	56	75	---	1149	---	450	56
	mg/hr	177	505	---	2253	---	6919	284
	mg/kg fuel	40	22	---	1155	---	210	30
	mg/kW-hr	46	5	---	---	---	56	55
Benz-aldehyde	$\mu g/m^3$	---	---	---	237	654	---	158
	mg/hr	---	---	---	524	7701	---	904
	mg/kg fuel	---	---	---	269	133	---	95
	mg/kW-hr	---	---	---	---	33	---	174

TABLE D-52. ALDEHYDES BY DNPH FOR CATERPILLAR 3406, 18° BTC

		1260 rpm				2100 rpm		
Aldehyde	Rate	2	50	100	Idle	100	50	2
Form-aldehyde	μg/m^3	1227	1347	5185	2602	1896	2416	8651
	mg/hr	3356	1039	1275	967	3116	3051	9014
	mg/kg fuel	725	47	29	576	53	97	887
	mg/kW-hr	818	11	7	---	14	27	1918
Acet-aldehyde	μg/m^3	2308	---	---	927	---	---	2535
	mg/hr	3228	---	---	745	---	---	5708
	mg/kg fuel	698	---	---	444	---	---	562
	mg/kW-hr	787	---	---	---	---	---	1215
Acetone	μg/m^3	325	---	---	262	---	---	285
	mg/hr	780	---	---	362	---	---	1102
	mg/kg fuel	169	---	---	216	---	---	109
	mg/kW-hr	190	---	---	---	---	---	235
Iso-butanal	μg/m^3	155	146	105	351	---	59	363
	mg/hr	576	647	626	750	---	428	2175
	mg/kg fuel	124	29	14	447	---	14	214
	mg/kW-hr	140	7	3	---	---	38	463
Crotonal	μg/m^3	386	343	102	472	234	72	496
	mg/hr	1365	1446	581	959	2099	498	2824
	mg/kg fuel	295	65	13	571	36	16	278
	mg/kW-hr	333	15	3	---	9	4	601
Hexanal	μg/m^3	246	36	56	110	344	37	72
	mg/hr	1774	313	647	454	1324	516	4002
	mg/kg fuel	383	14	15	270	23	16	394
	mg/kW-hr	433	3	3	---	6	5	851
Benz-aldehyde	μg/m^3	3526	227	1028	185	19	516	509
	mg/hr	28431	2182	2490	857	372	8126	6602
	mg/kg fuel	6145	99	56	510	6	260	650
	mg/kW-hr	6934	23	13	---	2	72	1405

TABLE D-53. ALDEHYDES BY DNPH FOR CATERPILLAR 3406, 33° BTC

		1260 rpm				2100 rpm		
Aldehyde	Rate	2	50	100	Idle	100	50	2
Form-aldehyde	$\mu g/m^3$	4339	2184	2267	40263	3559	3559	3800
	mg/hr	2864	1688	2353	15092	5679	4439	3923
	mg/kg fuel	601	76	54	7233	100	139	376
	mg/kW-hr	754	18	13	---	23	36	835
Acet-aldehyde	$\mu g/m^3$	618	---	---	3701	---	---	351
	mg/hr	882	---	---	2999	---	---	782
	mg/kg fuel	185	---	---	1437	---	---	75
	mg/kW-hr	232	---	---	---	---	---	166
Acetone	$\mu g/m^3$	177	386	3	3333	---	---	327
	mg/hr	435	1107	13	4640	---	---	1254
	mg/kg fuel	91	50	0	2224	---	---	120
	mg/kW-hr	115	12	0	---	---	---	267
Iso-butyr-aldehyde	$\mu g/m^3$	249	246	70	1261	74	72	438
	mg/hr	946	1091	417	2717	683	515	2601
	mg/kg fuel	199	49	10	1302	12	16	249
	mg/kW-hr	249	12	2	---	3	4	553
Crotonal	$\mu g/m^3$	718	2888	829	1464	1210	1750	2349
	mg/hr	2590	12204	4703	2999	10552	11926	13249
	mg/kg fuel	544	548	108	1437	185	375	1270
	mg/kW-hr	682	130	25	---	43	98	2819
Hexanal	$\mu g/m^3$	86	990	467	411	987	664	478
	mg/hr	636	8526	5400	1718	17545	9234	5499
	mg/kg fuel	134	383	124	824	308	290	527
	mg/kW-hr	167	91	29	---	72	76	1170
Benz-aldehyde	$\mu g/m^3$	701	35	---	3289	---	92	184
	mg/hr	5764	341	---	15359	---	1433	2372
	mg/kg fuel	1210	15	---	7361	---	45	227
	mg/kW-hr	1517	4	---	---	---	12	505

TABLE D-54. ALDEHYDES BY DNPH FOR CATERPILLAR 3406, IDI ENGINE
STANDARD TIMING, 10° BTC

		1400 rpm				2100 rpm		
Aldehyde	Rate	2	50	100	Idle	100	50	2
Form-aldehyde	$\mu g/m^3$	9915	0	976	2674	920	966	2156
	mg/hr	6638	0	1175	805	1542	1115	1983
	mg/kg fuel	1100	0	24	467	25	34	177
	mg/kW-hr	1897	0	6	---	6	9	381
Acet-aldehyde	$\mu g/m^3$	2648	101	0	1431	25	0	315
	mg/hr	3832	181	0	931	91	0	627
	mg/kg fuel	635	8	0	540	2	0	56
	mg/kW-hr	1095	2	0	---	0	0	121
Acetone	$\mu g/m^3$	0	68	68	498	29	0	68
	mg/hr	0	209	303	557	181	0	231
	mg/kg fuel	0	9	6	323	3	0	21
	mg/kW-hr	0	2	2	---	1	0	45
Iso-butyr-aldehyde	$\mu g/m^3$	923	0	0	0	0	0	0
	mg/hr	3554	0	0	0	0	0	0
	mg/kg fuel	589	0	0	0	0	0	0
	mg/kW-hr	1015	0	0	0	0	0	0
Crotonal	$\mu g/m^3$	0	63	321	432	452	472	464
	mg/hr	0	288	2114	711	4142	2978	2334
	mg/kg fuel	0	12	42	413	66	90	208
	mg/kW-hr	0	3	11	---	17	24	449
Hexanal	$\mu g/m^3$	158	39	42	72	42	42	42
	mg/hr	1182	360	559	242	779	536	428
	mg/kg fuel	196	15	11	141	12	16	38
	mg/kW-hr	338	4	3	---	3	4	82
Benz-aldehyde	$\mu g/m^3$	906	335	361	461	406	335	445
	mg/hr	7562	3462	5415	1729	8473	4813	5105
	mg/kg fuel	1253	146	109	1003	135	146	456
	mg/kW-hr	2160	35	27	---	35	39	982

TABLE D-55. SPECIFIC HYDROCARBON EMISSION RATES, CATERPILLAR 3406 28° BTC

		1260 rpm				2100 rpm		
Hydrocarbon	Rate	2	50	100	Idle	100	50	2
Methane	μg/m^3	4328	2265	1398	5860	799	1598	3996
CH_4	mg/hr	2092	1281	1038	1525	933	1505	3057
	mg/kg fuel	465	57	24	726	16	45	294
	mg/kW-hr	550	13	6	---	4	12	728
Ethylene	μg/m^3	14099	6234	4311	19867	6001	6642	13983
C_2H_4	mg/hr	6812	3527	3199	5168	7007	6255	10695
	mg/kg fuel	1514	158	74	2461	121	187	1029
	mg/kW-hr	1793	36	17	---	29	51	2546
Ethane	μg/m^3	250	187	---	499	62	125	187
C_2H_6	mg/hr	121	106	---	130	73	118	143
	mg/kg fuel	27	5	---	62	1	4	14
	mg/Kw-hr	32	1	---	---	0	1	34
Acetylene	μg/m^3	1245	595	433	1895	758	541	1407
C_2H_2	mg/hr	601	336	321	492	884	509	1075
	mg/kg fuel	134	15	7	234	15	15	103
	mg/kW-hr	158	3	2	---	4	4	256
Propane	μg/m^3	---	---	---	---	---	---	---
C_3H_8	mg/hr	---	---	---	---	---	---	---
	mg/kg fuel	---	---	---	---	---	---	---
	mg/kW-hr	---	---	---	---	---	---	---
Propylene	μg/m^3	3845	2447	1224	5710	2039	2622	4137
C_3H_6	mg/hr	1858	1384	908	1485	2381	2469	3164
	mg/kg fuel	413	62	21	707	41	74	304
	mg/kW-hr	489	14	5	---	10	20	753
Benzene	μg/m^3	1124	1236	674	1573	674	955	1124
C_6H_6	mg/hr	522	673	481	394	758	866	827
	mg/kg fuel	116	30	11	188	13	26	80
	mg/kW-hr	137	7	3	---	3	7	197
Toluene	μg/m^3	438	164	55	877	110	219	438
C_7H_8	mg/hr	211	93	41	227	128	206	334
	mg/kg fuel	47	4	1	108	2	6	32
	mg/kW-hr	56	1	0	---	1	2	80

TABLE D-56. SPECIFIC HYDROCARBON EMISSION RATES, CATERPILLAR 3406
28° BTC WITH EGR

		1260 rpm				2100 rpm		
Hydrocarbon	Rate	2	50	100	Idle	100	50	2
Methane	μg/m^3	3130	4395	1066	3130	599	2198	4129
CH_4	mg/hr	666	1979	758	414	423	2261	1413
	mg/kg fuel	151	87	17	212	7	69	148
	mg/kW-hr	175	21	4	---	2	18	272
Ethylene	μg/m^3	13925	11303	4137	12060	6700	9438	15265
C_2H_4	mg/hr	2961	5088	2941	1596	4727	9707	5223
	mg/kg fuel	671	221	68	818	82	295	548
	mg/kW-hr	779	53	16	---	20	78	1004
Ethane	μg/m^3	187	375	---	312	---	187	312
C_2H_6	mg/hr	40	169	---	41	---	193	107
	mg/kg fuel	9	7	---	21	---	6	11
	mg/kW-hr	10	2	---	---	---	2	21
Acetylene	μg/m^3	1678	1732	433	1462	704	1083	2382
C_2H_2	mg/hr	356	779	308	193	496	1112	814
	mg/kg fuel	81	34	7	99	9	34	85
	mg/kW-hr	94	8	2	---	2	9	157
Propane	μg/m^3	---	---	---	---	---	---	---
C_3H_8	mg/hr	---	---	---	---	---	---	---
	mg/kg fuel	---	---	---	---	---	---	---
	mg/kW-hr	---	---	---	---	---	---	---
Propylene	μg/m^3	3437	3146	990	3088	2214	2913	3787
C_3H_6	mg/hr	731	1416	704	409	1562	2996	1296
	mg/kg/ fuel	166	62	16	209	27	91	136
	mg/kW-hr	192	15	4	---	7	24	249
Benzene	μg/m^3	1292	2416	674	1292	786	1517	1910
C_6H_6	mg/hr	264	1046	461	165	534	1501	629
	mg/kg fuel	60	46	11	84	9	46	66
	mg/kW-hr	70	11	2	---	2	12	121
Toluene	μg/m^3	329	438	55	384	110	384	493
C_7H_8	mg/hr	70	197	39	51	77	393	168
	mg/kg fuel	16	9	1	26	1	12	18
	mg/kW-hr	18	2	0	---	0	3	32

TABLE D-57. SPECIFIC HYDROCARBON EMISSION RATES, CATERPILLAR 3406 18° BTC

		1260 rpm				2100 rpm		
Hydrocarbon	Rate	2	50	100	Idle	100	50	2
Methane	$\mu g/m^3$	4195	2531	666	2464	732	2397	4329
CH_4	mg/hr	2026	1456	516	683	898	2259	3365
	mg/kg fuel	438	66	12	407	15	72	331
	mg/kW-hr	494	15	3	---	4	21	716
Ethylene	$\mu g/m^3$	12293	6991	4137	6118	5710	7690	12002
C_2H_4	mg/hr	5934	4021	3206	1696	7000	7244	9327
	mg/kg fuel	1283	181	72	1011	119	231	918
	mg/kW-hr	1447	43	17	---	31	64	1985
Ethane	$\mu g/m^3$	375	187	---	187	62	187	250
C_2H_6	mg/hr	181	108	---	52	77	176	194
	mg/kg fuel	39	5	---	31	1	6	19
	mg/kW-hr	44	1	---	---	0	2	41
Acetylene	$\mu g/m^3$	1245	650	217	595	433	866	1245
C_2H_2	mg/hr	600	373	168	165	530	815	966
	mg/kg fuel	130	17	4	98	9	26	95
	mg/kW-hr	146	4	1	---	2	7	206
Propane	$\mu g/m^3$	115	---	---	---	---	---	---
C_3H_8	mg/hr	59	---	---	---	---	---	---
	mg/kg fuel	13	---	---	---	---	---	---
	mg/kW-hr	14	---	---	---	---	---	---
Propylene	$\mu g/m^3$	4370	2447	1457	2156	1806	2680	4428
C_3H_6	mg/hr	2109	1407	1129	598	2214	2524	3441
	mg/kg fuel	456	64	26	356	38	81	339
	mg/kW-hr	514	15	6	---	10	22	732
Benzene	$\mu g/m^3$	1348	1629	506	1011	618	1404	1573
C_6H_6	mg/hr	626	902	377	270	729	1273	1176
	mg/kg fuel	135	41	9	161	12	41	116
	mg/kW-hr	153	10	2	---	3	11	250
Toluene	$\mu g/m^3$	438	274	110	329	164	274	493
C_7H_8	mg/hr	211	157	85	91	201	257	382
	mg/kg fuel	46	7	2	54	3	8	38
	mg/kW-hr	51	2	0.5	---	1	2	81

TABLE D-58. SPECIFIC HYDROCARBON EMISSION RATES, CATERPILLAR 3406 33° BTC

		1260 rpm				2100 rpm		
Hydrocarbon	Rate	2	50	100	Idle	100	50	2
Methane CH_4	$\mu g/m^3$	6859	3729	1798	8524	666	1132	3663
	mg/hr	3378	2151	1392	2384	793	1053	2821
	mg/kg fuel	709	97	32	1142	14	33	270
	mg/kW-hr	889	23	7	0	3	9	600
Ethylene C_2H_4	$\mu g/m^3$	26626	8273	3554	30180	6292	4311	15265
	mg/hr	13108	4771	2751	8438	7489	4011	11752
	mg/kg fuel	2752	214	63	4044	132	126	1126
	mg/kW-hr	3450	51	15	0	31	33	2500
Ethane C_2H_6	$\mu g/m^3$	437	437	---	562	---	125	250
	mg/hr	215	252	---	157	---	116	192
	mg/kg fuel	45	11	---	75	---	4	18
	mg/kW-hr	57	3	---	0	---	1	41
Acetylene C_2H_2	$\mu g/m^3$	2382	1245	379	2273	650	487	1678
	mg/hr	1171	717	293	635	772	453	1290
	mg/kg fuel	246	32	7	304	14	14	124
	mg/kW-hr	308	8	2	0	3	4	275
Propane C_3H_8	$\mu g/m^3$	---	58	---	---	---	---	---
	mg/hr	---	35	---	---	---	---	---
	mg/kg fuel	---	2	---	---	---	---	---
	mg/kW-hr	---	0	---	---	---	---	---
Propylene C_3H_6	$\mu g/m^3$	6700	2913	1049	7865	2097	1806	3904
	mg/hr	3299	1680	812	2199	2496	1680	3005
	mg/kg fuel	693	75	19	1054	44	53	288
	mg/kW-hr	868	18	4	0	10	14	639
Benzene C_6H_6	$\mu g/m^3$	1854	1854	674	2022	843	562	1011
	mg/hr	878	1029	502	544	965	503	749
	mg/kg fuel	184	46	12	261	17	16	72
	mg/kW-hr	231	11	3	0	4	4	159
Toluene C_7H_8	$\mu g/m^3$	438	219	---	767	---	---	---
	mg/hr	215	126	---	214	---	---	---
	mg/kg fuel	45	6	---	103	---	---	---
	mg/kW-hr	57	1	---	0	---	---	---

TABLE D-59. SPECIFIC HYDROCARBON EMISSION RATES, CATERPILLAR 3406 IDI, STANDARD TIMING 10° BTC

		1400 rpm				2100 rpm		
Hydrocarbon	Rate	2	50	100	Idle	100	50	2
Methane	$\mu g/m^3$	2704	433	333	2158	286	693	1332
CH_4	mg/hr	1350	268	299	484	358	596	914
	mg/kg fuel	224	11	6	281	6	18	82
	mg/kW-hr	386	3	2	---	2	5	176
Ethylene	$\mu g/m^3$	15457	1981	2610	8955	5675	3088	4515
C_2H_4	mg/hr	7719	1227	2344	2010	7093	2658	3099
	mg/kg fuel	1279	52	47	1166	113	81	277
	mg/kW-hr	2205	12	12	---	29	22	596
Ethane	$\mu g/m^3$	106	6	0	19	0	12	12
C_2H_6	mg/hr	53	4	0	4	0	11	9
	mg/kg fuel	9	0	0	2	0	0	1
	mg/kW-hr	15	0	0	---	0	0	2
Acetylene	$\mu g/m^3$	1618	162	395	942	628	466	752
C_2H_2	mg/hr	807	101	354	211	784	400	516
	mg/kg fuel	134	4	7	123	13	12	46
	mg/kW-hr	231	1	2	---	3	3	99
Propane	$\mu g/m^3$	0	0	0	0	0	0	0
C_3H_8	mg/hr	0	0	0	0	0	0	0
	mg/kg fuel	0	0	0	0	0	0	0
	mg/kW-hr	0	0	0	0	0	0	0
Propylene	$\mu g/m^3$	4719	711	559	2226	1468	1066	1258
C_3H_6	mg/hr	2357	440	502	500	1835	918	864
	mg/kg fuel	391	19	10	290	29	28	77
	mg/kW-hr	673	4	3	---	8	7	166
Benzene	$\mu g/m^3$	1275	404	393	753	646	466	556
C_6H_6	mg/hr	613	241	340	163	777	387	367
	mg/kg fuel	102	10	7	94	12	12	33
	mg/kW-hr	175	2	2	---	3	3	71
Toluene	$\mu g/m^3$	1545	745	575	236	27	203	482
C_7H_8	mg/hr	770	460	515	53	34	174	330
	mg/kg fuel	128	19	10	31	1	5	30
	mg/kW-hr	220	5	3	---	0	1	64

TABLE D-60. 23-MODE EPA EXP DIESEL EMISSION CYCLE

DAIMLER-BENZ DIESEL ENGINE OM-352-AB S/N 909-10-01-9653 125 HR. EMISSION ENGINE
TEST 1 RUN 1 FUEL: FM-222-F PROJECT 11-4623-001 TEST DATE 1-3-78

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	600	0.0	0.0	.012	1.42	1.83	.007
2	1800	7.1	1.3	.051	5.45	5.50	.009
3	1800	28.5	5.4	.061	5.55	5.61	.011
4	1800	68.8	13.0	.083	5.59	5.67	.015
5	1800	99.7	18.8	.098	5.51	5.61	.018
6	1800	199.4	37.6	.155	6.08	6.23	.026
7	1800	294.4	55.5	.219	6.60	6.81	.032
8	1800	325.2	61.3	.242	6.73	7.02	.034
9	1800	365.6	68.9	.261	7.18	7.44	.036
10	1800	389.3	73.4	.271	7.16	7.43	.038
11	600	0.0	0.0	.012	1.83	1.85	.007
12	2800	351.3	103.0	.435	12.38	12.81	.035
13	2800	322.9	94.7	.402	11.83	12.23	.034
14	2800	289.6	84.9	.365	11.29	11.65	.032
15	2800	265.9	78.0	.342	11.06	11.41	.031
16	2800	178.0	52.2	.249	9.80	10.05	.025
17	2800	87.8	25.8	.167	8.62	8.78	.019
18	2800	66.5	19.5	.150	8.53	8.68	.018
19	2800	26.1	7.7	.124	8.33	8.46	.015
20	2800	9.5	2.8	.109	8.20	8.31	.013
21	600	0.0	0.0	.012	1.79	1.80	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	256	440	134	0.00	R	R	R	4.5
2	640	494	149	.10	76.36	117.39	58.24	4.5
3	616	464	190	.39	18.73	28.11	18.90	4.5
4	600	433	299	.79	7.64	10.47	12.46	4.1
5	592	375	386	.68	5.14	6.48	10.97	4.1
6	560	201	686	2.74	2.70	1.43	10.83	3.8
7	472	170	983	0.00	I	I	I	3.8
8	420	169	1084	3.00	1.40	1.13	11.82	4.0
9	384	169	1161	0.00	I	I	I	4.2
10	364	223	1198	0.00	I	I	I	3.9
11	920	525	79	0.00	R	R	R	4.1
12	356	495	982	3.30	1.29	3.57	11.64	4.1
13	388	443	951	6.34	1.46	3.32	11.71	4.1
14	372	390	878	3.65	1.48	3.10	11.47	4.1
15	392	391	811	5.69	1.67	3.32	11.30	4.5
16	480	313	613	3.81	2.69	3.49	11.25	4.5
17	584	456	388	0.00	I	I	I	4.5
18	632	486	314	1.54	8.19	12.54	13.34	4.5
19	720	599	224	0.00	I	I	I	4.8
20	764	601	181	0.00	I	I	I	4.8
21	736	525	134	0.00	R	R	R	4.8

CYCLE COMPOSITE
BSHC = 3.080 GRAM/KW HR
BSCO+ = 4.809 GRAM/KW HR
BSNO2++= 11.963 GRAM/KW HR
BSHC + BSNO2++= 15.043 GRAM/KW HR
BSFC = .289KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE D-61. 23-MODE EPA EXP DIESEL EMISSION CYCLE

DAIMLER-BENZ DIESEL ENGINE OM-352-AB S/N 909-10-01-9653 125 HR. EMISSION ENGINE
TEST 1 RUN 2 FUEL: EM-222-F PROJECT 11-4623-001 TEST DATE 1-3-78

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	600	0.0	0.0	.013	1.80	1.81	.007
2	1800	7.1	1.3	.051	5.50	5.55	.009
3	1800	28.5	5.4	.063	5.53	5.60	.011
4	1800	68.8	13.0	.083	5.58	5.67	.015
5	1800	99.7	18.8	.098	5.62	5.72	.017
6	1800	201.8	38.0	.156	6.13	6.29	.026
7	1800	296.7	55.9	.215	6.60	6.81	.033
8	1800	325.2	61.3	.237	6.92	7.15	.034
9	1800	363.2	68.5	.259	7.12	7.38	.036
10	1800	389.3	73.4	.271	7.12	7.39	.038
11	600	0.0	0.0	.012	1.79	1.80	.007
12	2800	353.7	103.7	.436	12.46	12.89	.035
13	2800	325.2	95.4	.407	11.72	12.12	.035
14	2800	289.6	84.9	.367	11.26	11.63	.033
15	2800	265.9	78.0	.342	10.90	11.24	.031
16	2800	178.0	52.2	.249	9.57	9.82	.026
17	2800	85.5	25.1	.168	8.39	8.56	.020
18	2800	61.7	18.1	.148	8.36	8.51	.018
19	2800	28.5	8.4	.121	8.21	8.33	.015
20	2800	7.1	2.1	.107	8.17	8.28	.013
21	600	0.0	0.0	.012	1.74	1.75	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	848	495	124	0.00	R	R	R	5.8
2	720	521	150	.10	86.64	125.00	59.29	5.8
3	708	519	198	.39	21.48	31.36	19.62	5.8
4	668	487	306	.79	8.44	12.33	12.73	5.8
5	712	402	393	.68	6.36	7.14	11.49	5.8
6	620	257	686	2.78	2.98	2.46	10.80	5.8
7	584	225	995	0.00	I	I	I	5.8
8	564	197	1087	3.00	1.92	1.33	12.08	5.6
9	488	212	1167	0.00	I	I	I	5.6
10	408	223	1227	0.00	I	I	I	5.6
11	808	354	145	0.00	R	R	R	5.6
12	304	441	1039	3.32	1.10	3.18	12.31	5.6
13	328	441	1015	6.39	1.21	3.25	12.29	5.6
14	392	362	939	3.65	1.56	2.67	12.25	6.2
15	392	281	885	5.69	1.64	2.35	12.15	6.2
16	476	228	677	3.81	2.61	2.49	12.13	6.2
17	608	288	417	0.00	I	I	I	6.2
18	696	317	329	1.43	9.52	8.64	14.72	6.2
19	784	376	237	0.00	I	I	I	6.2
20	848	433	184	0.00	I	I	I	6.2
21	792	353	146	0.00	R	R	R	6.2

CYCLE COMPOSITE BSHC = 3.227 GRAM/KW HR
BSCO+ = 4.311 GRAM/KW HR
BSNO2++= 12.628 GRAM/KW HR
BSHC + BSNO2++= 15.854 GRAM/KW HR
BSFC = .291KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE D-62. 13-MODE FEDERAL DIESEL EMISSION CYCLE

DAIMLER-BENZ DIESEL ENGINE OM-352-AB S/N 909-10-01-9653 125 HR. EMISSION ENGINE
TEST 1 RUN 1 FUEL: EM-272-F PROJECT 11-4623-001 TEST DATE 1-3-78

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	600	0.0	0.0	.012	1.82	1.83	.007
2	1800	7.1	1.3	.051	5.45	5.50	.009
3	1800	99.7	18.8	.098	5.51	5.61	.018
4	1800	199.4	37.6	.156	6.08	6.23	.026
5	1800	294.4	55.5	.214	6.60	6.81	.032
6	1800	389.3	73.4	.271	7.16	7.43	.038
7	600	0.0	0.0	.012	1.83	1.85	.007
8	2800	351.3	103.0	.435	12.39	12.81	.035
9	2800	265.9	78.0	.342	11.06	11.41	.031
10	2800	178.0	52.2	.249	9.80	10.05	.025
11	2800	87.8	25.8	.167	8.62	8.78	.019
12	2800	9.5	2.8	.108	8.20	8.31	.013
13	600	0.0	0.0	.012	1.79	1.80	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	756	440	132	0.00	R	R	R	4.5
2	640	494	132	.11	76.36	117.39	51.73	4.5
3	542	375	349	1.50	5.14	6.48	9.93	4.1
4	560	201	692	3.01	2.70	1.93	10.92	3.8
5	472	170	1007	4.44	1.69	1.21	11.78	3.8
6	364	223	1183	5.87	1.07	1.31	11.41	3.9
7	920	525	104	0.00	R	R	R	4.1
8	356	495	1002	8.24	1.29	3.57	11.87	4.1
9	392	391	795	6.24	1.67	3.32	11.08	4.5
10	480	313	641	4.18	2.69	3.49	11.75	4.5
11	584	456	359	2.06	5.80	4.02	11.66	4.5
12	764	601	152	.22	66.38	104.00	43.13	4.8
13	736	525	88	0.00	R	R	R	4.8

CYCLE COMPOSITE BSHC = 2.940 GRAM/KW HR
BSCO+ = 4.413 GRAM/KW HR
BSNO2++= 11.877 GRAM/KW HR
BSHC + BSNO2++= 14.816 GRAM/KW HR
BSFC = .284KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE D-63. 13-MODE FEDERAL DIESEL EMISSION CYCLE

DAIMLER-BENZ DIESEL ENGINE OM-352 AB S/N 909-10-01-9653 125 HR. EMISSION ENGINE
TEST 1 RUN 2 FUEL: EM-272-F PROJECT 11-4623-001 TEST DATE 1-3-78

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	600	0.0	0.0	.013	1.80	1.81	.007
2	1800	7.1	1.3	.051	5.50	5.55	.009
3	1800	99.7	18.8	.098	5.67	5.77	.017
4	1800	201.8	38.0	.156	6.13	6.29	.026
5	1800	296.7	55.9	.215	6.60	6.81	.033
6	1800	389.3	73.4	.271	7.12	7.39	.038
7	600	0.0	0.0	.012	1.79	1.80	.007
8	2800	353.7	103.7	.436	12.46	12.89	.035
9	2800	265.9	78.0	.342	10.90	11.24	.031
10	2800	178.0	52.2	.249	9.57	9.82	.026
11	2800	85.5	25.1	.168	8.39	8.56	.020
12	2800	7.1	2.1	.107	8.17	8.28	.013
13	600	0.0	0.0	.012	1.74	1.75	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	848	495	72	0.00	R	R	R	5.8
2	720	521	90	.11	86.69	125.00	35.58	5.8
3	712	402	321	1.50	6.36	7.14	9.38	5.8
4	620	257	653	3.04	2.98	2.46	10.28	5.8
5	584	225	994	4.47	2.07	1.54	11.53	5.8
6	408	223	1202	5.87	1.20	1.30	11.53	5.6
7	808	354	123	0.00	R	R	R	5.6
8	304	441	1016	8.30	1.10	3.18	12.03	5.6
9	392	281	846	6.24	1.64	2.35	11.62	6.2
10	476	228	686	4.18	2.61	2.49	12.30	6.2
11	608	288	404	2.00	6.04	5.70	13.15	6.2
12	848	433	151	.17	97.81	99.44	56.97	6.2
13	792	353	105	0.00	R	R	R	6.2

CYCLE COMPOSITE BSHC = 3.107 GRAM/KW HR
BSCO+ = 3.741 GRAM/KW HR
BSNO2++= 12.026 GRAM/KW HR
BSHC + BSNO2++= 15.133 GRAM/KW HR
BSFC = .284KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE D-64.   21-MODE EPA EXP DIESEL EMISSION CYCLE

PROJECT: 11-4623-001   TEST DATE 3-31-78   RUN NO.1
ENGINE: DAIMLER-BENZ MODEL OM-352 N/A DI   SERIAL NO. 12488

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	600	0.0	0.0	.011	1.89	1.90	.006
2	2000	7.1	1.5	.056	6.13	6.18	.009
3	2000	26.1	5.5	.065	6.15	6.21	.011
4	2000	59.3	12.4	.083	6.00	6.08	.014
5	2000	87.8	18.4	.101	6.06	6.16	.017
6	2000	180.4	37.8	.160	6.08	6.24	.026
7	2000	258.8	54.2	.215	6.00	6.22	.036
8	2000	284.9	59.7	.237	5.98	6.22	.040
9	2000	315.7	66.1	.265	5.96	6.22	.044
10	2000	341.8	71.6	.293	5.89	6.19	.050
11	600	0.0	0.0	.013	1.85	1.86	.007
12	2800	315.7	92.6	.411	8.00	8.41	.051
13	2800	292.0	85.6	.372	8.02	8.39	.046
14	2800	261.1	76.6	.327	8.04	8.37	.041
15	2800	237.4	69.6	.297	8.06	8.36	.037
16	2800	159.1	46.6	.219	8.13	8.35	.027
17	2800	83.1	24.4	.159	8.10	8.26	.020
18	2800	57.0	16.7	.136	8.09	8.22	.017
19	2800	26.1	7.7	.112	8.07	8.18	.014
20	2800	7.1	2.1	.099	8.06	8.16	.012
21	600	0.0	0.0	.013	1.90	1.91	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	748	464	131	0.00	R	R	R	11.0
2	700	517	141	.11	84.43	124.20	55.61	11.0
3	712	542	180	.40	23.54	35.72	19.43	11.0
4	824	566	263	.76	11.73	16.07	12.24	11.0
5	832	536	338	.66	8.11	10.41	10.79	11.0
6	800	418	691	2.76	3.85	4.00	10.88	11.0
7	680	383	958	0.00	I	I	1	11.0
8	576	433	1017	2.92	1.75	2.61	10.09	11.0
9	440	685	1047	0.00	I	I	I	11.0
10	220	1403	1042	0.00	I	I	I	11.0
11	824	463	136	0.00	R	R	R	11.0
12	24	1474	1005	2.96	.06	7.77	8.69	11.0
13	120	1084	996	5.74	.34	6.16	9.30	11.0
14	308	613	968	3.29	.98	3.88	10.08	11.0
15	456	462	921	5.08	1.59	3.21	10.53	11.0
16	628	471	665	3.40	3.27	4.89	11.33	11.0
17	740	560	363	0.00	I	1	1	10.3
18	792	591	270	1.32	11.34	16.87	12.66	10.3
19	824	621	195	0.00	I	I	I	10.3
20	824	623	156	0.00	I	I	I	10.3
21	880	520	95	0.00	R	R	R	10.3

CYCLE COMPOSITE BSHC = 3.410 GRAM/KW HR
BSCO+ = 7.010 GRAM/KW HR
BSNO2++= 10.766 GRAM/KW HR
BSHC + BSNO2++= 14.175 GRAM/KW HR
BSFC = .295KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE D-65. 21-MODE EPA EXP DIESEL EMISSION CYCLE

PROJECT: 11-4623-001 TEST DATE 3-31-78 RUN NO.2
ENGINE: DAIMLER-BENZ MODEL OM-352 N/A DI SERIAL NO. 12488

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	600	0.0	0.0	.011	1.89	1.90	.006
2	2000	9.5	2.0	.055	6.10	6.15	.009
3	2000	28.5	6.0	.068	6.12	6.18	.011
4	2000	61.7	12.9	.087	6.12	6.20	.014
5	2000	85.5	17.9	.100	6.05	6.15	.016
6	2000	182.8	38.3	.161	6.03	6.19	.027
7	2000	258.8	54.2	.215	6.01	6.22	.036
8	2000	280.1	58.7	.233	5.96	6.19	.039
9	2000	315.7	66.1	.266	5.96	6.23	.045
10	2000	341.8	71.6	.293	5.96	6.26	.049
11	600	0.0	0.0	.011	1.84	1.86	.006
12	2800	315.7	92.6	.410	8.01	8.42	.051
13	2800	292.0	85.6	.370	8.02	8.39	.046
14	2800	261.1	76.6	.330	8.08	8.41	.041
15	2800	237.4	69.6	.310	8.13	8.44	.038
16	2800	161.4	47.3	.229	8.19	8.42	.028
17	2800	80.7	23.7	.156	8.14	8.30	.019
18	2800	57.0	16.7	.138	8.23	8.37	.017
19	2800	28.5	8.4	.113	8.07	8.19	.014
20	2800	7.1	2.1	.096	8.06	8.15	.012
21	600	0.0	0.0	.014	1.81	1.82	.008

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	UM. ILLI /KG
1	856	408	110	0.00	R	R	R	0.8
2	740	433	149	.15	66.61	77.69	43.82	0.8
3	788	431	188	.44	23.77	25.93	18.57	0.8
4	808	429	265	.79	11.28	11.93	12.11	0.8
5	824	399	325	.64	8.24	7.46	10.65	0.8
6	800	254	689	2.79	3.76	2.38	10.61	0.8
7	704	222	918	0.00	I	I	I	0.8
8	640	248	1006	2.87	1.97	1.52	10.12	0.8
9	460	507	1039	0.00	I	I	I	9.4
10	212	1332	1038	0.00	I	I	I	9.4
11	856	323	135	0.00	R	R	R	9.4
12	24	1362	979	2.96	.06	7.18	8.46	9.4
13	120	1112	969	5.74	.34	6.32	9.04	9.4
14	288	666	927	3.29	.92	4.24	9.69	9.4
15	424	540	831	5.08	1.50	3.80	9.60	9.4
16	600	498	624	3.45	3.10	5.14	10.57	9.4
17	712	615	346	0.00	I	I	I	9.4
18	796	619	267	1.32	11.60	17.97	12.74	9.4
19	848	622	192	0.00	I	I	I	9.6
20	880	625	155	0.00	I	I	I	9.6
21	880	492	107	0.00	R	R	R	9.6

CYCLE COMPOSITE
BSHC = 3.446 GRAM/KW HR
BSCO+ = 6.510 GRAM/KW HR
BSNO2++= 10.369 GRAM/KW HR
BSHC + BSNO2++= 13.815 GRAM/KW HR
BSFC = .298KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE D-66. 13-MODE FEDERAL DIESEL EMISSION CYCLE

PROJECT: 11-4623-001 TEST DATE 3-31-78 RUN NO.1
ENGINE: DAIMLER-BENZ MODEL OM-352 N/A DI SERIAL NO. 12488

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	600	0.0	0.0	.011	1.89	1.90	.006
2	2000	7.1	1.5	.056	6.13	6.18	.009
3	2000	87.8	18.4	.101	6.06	6.16	.017
4	2000	180.4	37.8	.160	6.08	6.24	.026
5	2000	258.8	54.2	.215	6.00	6.22	.036
6	2000	341.8	71.6	.293	5.89	6.19	.050
7	600	0.0	0.0	.013	1.85	1.86	.007
8	2800	315.7	92.6	.411	8.00	8.41	.051
9	2800	237.4	69.6	.297	8.06	8.36	.037
10	2800	159.1	46.6	.219	8.13	8.35	.027
11	2800	83.1	24.4	.159	8.10	8.26	.020
12	2800	7.1	2.1	.099	8.06	8.16	.012
13	600	0.0	0.0	.013	1.90	1.91	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	748	464	110	0.00	R	R	R	11.0
2	700	517	120	.12	84.43	124.20	47.27	11.0
3	832	536	287	1.47	8.11	10.41	9.16	11.0
4	800	418	657	3.02	3.85	4.00	10.34	11.0
5	680	383	920	4.34	2.27	2.55	10.05	11.0
6	220	1403	956	5.73	.55	7.03	7.87	11.0
7	824	463	100	0.00	R	R	R	11.0
8	24	1474	983	7.41	.06	7.77	8.51	11.0
9	456	462	902	5.57	1.59	3.21	10.32	11.0
10	628	471	654	3.73	3.27	4.89	11.15	11.0
11	740	560	369	1.95	7.30	11.01	11.93	10.3
12	824	623	147	.17	93.69	141.23	54.68	10.3
13	880	520	89	0.00	R	R	R	10.3

CYCLE COMPOSITE BSHC = 3.198 GRAM/KW HR
BSCO+ = 7.252 GRAM/KW HR
BSNO2++= 10.064 GRAM/KW HR
BSHC + BSNO2++= 13.262 GRAM/KW HR
BSFC = .293KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE D-67. 13-MODE FEDERAL DIESEL EMISSION CYCLE

PROJECT: 11-4623-001 TEST DATE 3-31-78 RUN NO.2
ENGINE: DAIMLER-BENZ MODEL OM-352 N/A DI SERIAL NO. 12488

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	600	0.0	0.0	.011	1.89	1.90	.006
2	2000	9.5	2.0	.055	6.10	6.15	.009
3	2000	85.5	17.9	.100	6.05	6.15	.016
4	2000	182.8	38.3	.161	6.03	6.19	.027
5	2000	258.8	54.2	.215	6.01	6.22	.036
6	2000	341.8	71.6	.293	5.96	6.26	.049
7	600	0.0	0.0	.011	1.84	1.86	.006
8	2800	315.7	92.6	.410	8.01	8.42	.051
9	2800	237.4	69.6	.310	8.13	8.44	.038
10	2800	161.4	47.3	.229	8.19	8.42	.028
11	2800	80.7	23.7	.156	8.14	8.30	.019
12	2800	7.1	2.1	.096	8.06	8.16	.012
13	600	0.0	0.0	.014	1.81	1.82	.008

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCU+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	856	408	109	0.00	R	R	R	10.8
2	740	433	139	.16	66.61	77.64	40.90	10.8
3	824	399	274	1.43	8.24	7.96	8.97	10.8
4	800	254	655	3.06	3.76	2.38	10.08	10.8
5	704	222	859	4.34	2.35	1.48	9.40	10.8
6	212	1332	959	5.73	.54	6.75	7.98	9.4
7	856	323	115	0.00	R	R	R	9.4
8	24	1362	940	7.41	.06	7.18	8.14	9.4
9	424	540	865	5.57	1.50	3.80	10.00	9.4
10	600	498	677	3.79	3.10	5.14	11.47	9.4
11	712	615	367	1.89	7.27	12.52	12.25	9.4
12	880	625	146	.17	100.03	141.51	54.26	9.4
13	880	492	96	0.00	R	R	R	9.4

CYCLE COMPOSITE BSHC = 3.210 GRAM/KW HR
BSCO+ = 6.740 GRAM/KW HR
BSNO2++= 9.903 GRAM/KW HR
BSHC + BSNO2++= 13.112 GRAM/KW HR
BSFC = .294KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE D-68. SUMMARY OF EXHAUST PARTICULATE FROM DAIMLER-BENZ OM-352A (BASED ON 47-mm GLASSFIBER FILTERS)

Engine rpm/% load	Run No.	Concentration mg/m^3	Particulate Rate		
			g/hr	g/kg fuel	g/kW-hr
1800/02	1	40.57	11.21	3.74	8.62
	2	44.49	12.00	4.14	9.23
	Avg	42.53	11.61	3.94	8.93
1800/25	1	34.78	10.18	1.73	0.56
	2	35.72	10.08	1.71	0.53
	Avg	35.25	10.13	1.72	0.55
1800/50	1	72.99	22.56	2.43	0.60
	2	62.54	19.12	2.06	0.51
	Avg	67.77	20.84	2.25	0.56
1800/75	1	60.11	20.70	1.57	0.36
	2	52.55	17.58	1.36	0.32
	Avg	56.33	19.14	1.47	0.34
1800/100	1	105.30	39.97	2.37	0.54
	2	106.73	40.14	2.39	0.54
	Avg	106.02	40.06	2.38	0.54
Idle	1	44.89	4.16	4.62	----
	2	46.08	4.33	6.19	----
	Avg	45.49	4.25	5.41	----
2800/100	1	84.27	53.68	2.01	0.50
	2	84.00	52.25	1.96	0.49
	Avg	84.14	52.96	1.99	0.50
2800/75	1	64.85	36.32	1.75	0.46
	2	62.24	35.05	1.68	0.44
	Avg	63.55	35.69	1.72	0.45
2800/50	1	83.44	41.69	2.71	0.77
	2	91.34	45.75	2.97	0.84
	Avg	87.39	43.72	2.84	0.81
2800/25	1	138.41	61.82	6.06	2.28
	2	134.30	59.82	5.86	2.21
	Avg	136.36	60.82	5.96	2.25
2800/02	1	93.61	38.17	6.58	18.18
	2	103.77	42.34	7.30	20.16
	Avg	98.69	40.26	6.94	19.17

TABLE D-69. SUMMARY OF EXHAUST $SO_4^=$ FROM DAIMLER-BENZ OM-352A

(BASED ON 47 mm FLUOROPORE FILTERS)

Engine rpm/% load	Run No.	Concentration $\mu g/m^3$	Sulfate Rate			$SO_4^=$ as % Fuel S
			mg/hr	mg/kg fuel	mg/kW-hr	
1800/2	1	987.9	272.9	90.96	209.9	1.29
	2	1020.8	275.2	94.90	211.7	1.35
	Avg	1004.4	274.1	92.93	210.8	1.32
1800/25	1	926.0	270.9	45.92	14.80	0.65
	2	1031.8	291.2	49.36	15.17	0.70
	Avg	978.9	281.1	47.64	14.99	0.68
1800/50	1	2443.7	755.0	81.18	20.08	1.15
	2	2435.8	744.7	80.08	19.81	1.14
	Avg	2439.8	749.9	80.63	19.95	1.15
1800/75	1	2036.7	701.8	53.17	12.29	0.75
	2	1729.7	578.1	44.86	10.43	0.64
	Avg	1883.2	640.0	49.02	11.36	0.70
1800/100	1	2308.9	876.5	52.17	11.80	0.74
	2	2264.6	851.7	50.70	11.56	0.72
	Avg	2286.8	864.1	51.44	11.68	0.73
Idle	1	1948.4	180.5	200.56	------	2.84
	2	1697.3	159.3	227.57	------	3.23
	Avg	1822.9	169.9	214.07	------	3.04
2800/100	1	2677.6	1705.5	63.88	15.81	0.91
	2	2239.4	1392.9	52.17	13.03	0.74
	Avg	2458.5	1549.2	58.03	14.42	0.83
2800/75	1	1928.3	1079.8	52.16	13.57	0.74
	2	1653.6	931.3	44.56	11.58	0.63
	Avg	1791.0	1005.6	48.36	12.58	0.69
2800/50	1	2346.2	1175.0	76.30	21.64	1.08
	2	2198.7	1098.5	71.33	20.23	1.01
	Avg	2272.5	1136.8	73.82	20.94	1.04
2800/25	1	2342.2	1043.3	102.28	38.50	1.45
	2	2155.9	962.9	94.40	35.53	1.34
	Avg	2249.1	1003.1	98.34	37.02	1.40
2800/2	1	1438.1	586.4	101.10	279.24	1.43
	2	1667.3	680.3	117.29	323.95	1.66
	Avg	1552.7	633.4	109.2	301.6	1.55

TABLE D-70.CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
DAIMLER-BENZ OM-352A ENGINE (RUN 1)
(13-MODE FTP WEIGHTING FACTORS)

							Weighted			
Engine rpm	% Load	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr
Idle	---	-----	0.9	4.16	180.5	0.067	----	0.06	0.28	12.09
1800	2	1.3	3.0	11.21	272.9	0.08	0.10	0.24	0.90	21.83
1800	25	18.3	5.9	10.18	270.9	0.08	1.46	0.47	0.81	21.67
1800	50	37.6	9.3	22.56	755.0	0.08	3.01	0.74	1.80	60.40
1800	75	57.1	13.2	20.70	701.8	0.08	4.57	1.06	1.66	56.14
1800	100	74.3	16.9	39.97	876.5	0.08	5.94	1.35	3.20	70.12
Idle		-----	0.9	4.16	180.5	0.067	----	0.06	0.28	12.09
2800	100	107.9	26.7	53.68	1705.5	0.08	8.63	2.14	4.29	136.44
2800	75	79.6	20.7	36.32	1079.8	0.08	6.37	1.66	2.91	86.38
2800	50	54.3	15.4	41.69	1175.0	0.08	4.34	1.23	3.34	94.00
2800	25	27.1	10.2	61.82	1043.3	0.08	2.17	0.82	4.95	83.46
2800	2	2.1	5.8	38.17	586.4	0.08	0.17	0.46	3.05	46.91
Idle	---	-----	0.9	4.16	180.5	0.067	----	0.06	0.28	12.09
							36.76	10.35	27.75	713.62

Brake Specific Particulate, g/kW-hr	0.755
Fuel Specific Particulate, g/kg fuel	2.681
Brake Specific $SO_4^=$, mg/kW-hr	19.41
Fuel Specific $SO_4^=$, mg/kg fuel	68.95

TABLE D-71. CYCLE COMPOSITE, PARTICULATE AND SULFATE RATES DAIMLER-BENZ OM-352A ENGINE (RUN 2)

(13-MODE FTP WEIGHTING FACTORS)

							Weighted			
Engine rpm	% Load	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr
Idle	---	-----	0.7	4.33	159.3	.067	----	0.05	0.29	10.67
1800	2	1.3	2.9	12.00	275.2	.08	0.10	0.23	0.96	22.02
1800	25	19.2	5.9	10.08	291.2	.08	1.54	0.47	0.81	23.30
1800	50	37.6	9.3	19.12	744.7	.08	3.01	0.74	1.53	59.58
1800	75	55.5	12.9	17.58	578.1	.08	4.44	1.03	1.41	46.25
1800	100	73.7	16.8	40.14	851.7	.08	5.90	1.34	3.21	68.14
Idle		-----	0.7	4.33	159.3	.067	----	0.05	0.29	10.67
2800	100	106.9	26.7	52.25	1392.9	.08	8.55	2.14	4.18	111.43
2800	75	80.4	20.9	35.05	931.3	.08	6.43	1.67	2.80	74.50
2800	50	54.3	15.4	45.75	1098.5	.08	4.34	1.23	3.66	87.88
2800	25	27.1	10.2	59.82	962.9	.08	2.17	0.82	4.79	77.03
2800	2	2.1	5.8	42.34	680.3	.08	0.17	0.46	3.39	54.42
Idle	---	-----	0.7	4.33	159.3	.067	----	0.05	0.29	10.67
							36.65	10.28	27.61	656.56

Brake Specific Particulate, g/kW-hr	0.753
Fuel Specific Particulate, g/kg fuel	2.686
Brake specific $SO_4^=$, mg/kW-hr	17.91
Fuel Specific $SO_4^=$, mg/kg fuel	63.87

TABLE D-72. SUMMARY OF EXHAUST PARTICULATE FROM DAIMLER-BENZ OM-352 NATURALLY ASPIRATED ENGINE (BASED ON 47 mm GLASSFIBER FILTERS)

Engine rpm, % Load	Run No.	Concentration mg/m^3	Particulate Rate		
			g/hr	g/kg fuel	g/kW-hr
2000/2	1	47.99	14.53	9.69	4.40
	2	50.07	15.12	10.08	4.58
	Avg	49.03	14.83	9.89	4.49
2000/25	1	98.90	30.72	5.12	1.72
	2	107.24	33.04	5.60	1.85
	Avg	103.07	31.88	5.36	1.79
2000/50	1	76.25	23.71	2.55	0.54
	2	81.34	25.32	2.72	0.59
	Avg	78.80	24.52	2.64	0.57
2000/75	1	99.06	30.48	2.38	0.56
	2	100.91	31.51	2.46	0.58
	Avg	99.99	31.00	2.42	0.57
2000/100	1	277.77	85.96	4.88	1.19
	2	283.69	87.96	5.00	1.22
	Avg	280.73	86.96	4.94	1.21
Idle	1	46.05	4.27	5.34	-----
	2	45.30	4.19	5.24	-----
	Avg	45.68	4.23	5.29	-----
2800/100	1	372.91	154.75	6.39	1.71
	2	354.21	146.68	5.94	1.60
	Avg	363.56	150.72	6.17	1.65
2800/75	1	126.79	53.66	2.95	0.76
	2	122.57	51.74	2.86	0.74
	Avg	124.68	52.70	2.91	0.75
2800/50	1	101.78	42.92	3.18	0.91
	2	100.71	42.37	3.14	0.90
	Avg	101.25	42.65	3.16	0.91
2900/25	1	140.05	58.20	6.33	2.49
	2	156.49	65.55	7.05	2.80
	Avg	148.27	61.88	6.69	2.65
2800/2	1	99.37	40.77	7.15	19.41
	2	121.10	49.60	8.86	23.62
	Avg	110.24	45.19	8.01	21.52

TABLE D-73. SUMMARY OF EXHAUST $SO_4^=$ FROM DAIMLER-BENZ OM-352 NATURALLY ASPIRATED ENGINE (BASED ON 47 mm FLUOROPORE FILTERS)

Engine rpm/% load	Run No.	Concentration $\mu g/m^3$	Sulfate Rate			$SO_4^=$ as % Fuel S
			mg/hr	mg/kg fuel	mg/kW-hr	
2000/2	1	767.0	232.2	70.37	154.8	0.98
	2	854.1	258.0	78.18	172.0	1.11
	Avg	810.6	245.1	74.28	163.4	1.05
2000/25	1	1186.5	365.5	61.95	20.42	0.88
	2	1236.5	379.8	62.26	20.64	0.88
	Avg	1211.5	372.7	62.11	20.53	0.88
2000/50	1	1878.1	584.0	62.80	15.87	0.89
	2	2349.2	731.2	78.62	19.87	1.11
	Avg	2113.7	657.6	70.71	17.87	1.00
2000/75	1	1127.8	352.2	27.52	6.50	0.39
	2	1874.7	582.1	45.83	10.74	0.65
	Avg	1501.3	467.2	36.68	8.62	0.52
2000/100	1	1881.6	579.9	33.33	8.11	0.47
	2	2206.0	684.0	38.86	9.49	0.55
	Avg	2043.8	632.0	36.10	8.80	0.51
Idle	1	1400.5	129.8	162.25	-----	2.30
	2	1749.8	164.1	205.13	-----	2.91
	Avg	1575.2	147.0	183.69	-----	2.61
2800/100	1	4080.0	1693.0	69.96	18.71	0.99
	2	2694.2	1115.7	45.17	12.15	0.64
	Avg	3387.1	1404.4	57.57	15.43	0.82
2800/75	1	3153.4	1334.4	73.32	18.98	1.04
	2	2554.9	1078.5	59.59	15.34	0.84
	Avg	2854.2	1206.5	66.46	17.16	0.94
2800/50	1	2535.5	1069.3	79.21	22.61	1.12
	2	2859.1	1202.7	89.09	25.43	1.26
	Avg	2697.3	1136.0	84.15	24.02	1.19
2800/25	1	1892.0	786.3	85.47	33.46	1.21
	2	2440.1	1022.0	109.90	43.68	1.56
	Avg	2166.1	904.2	97.69	38.57	1.39
2800/2	1	944.3	387.4	67.96	184.50	0.96
	2	1664.3	681.6	121.71	324.57	1.73
	Avg	1304.3	534.5	94.84	254.54	1.35

TABLE D-74. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES DAIMLER-BENZ OM-352 NATURALLY ASPIRATED ENGINE (13-MODE FTP WEIGHTING FACTORS) RUN 1

Engine rpm	% Load	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Weighted Power kW	Weighted Fuel kg/hr	Weighted Part. g/hr	Weighted $SO_4^=$ mg/hr
Idle	---	----	0.8	4.27	129.8	0.067	----	0.05	0.29	8.70
2000	2	1.5	3.3	14.53	232.2	0.08	0.12	0.26	1.16	18.58
2000	25	17.9	6.0	30.72	365.5	0.08	1.43	0.48	2.46	29.24
2000	50	36.8	9.3	23.71	584.0	0.08	2.94	0.74	1.90	46.72
2000	75	54.2	12.8	30.48	352.2	0.08	4.34	1.02	2.44	28.18
2000	100	72.0	17.6	85.96	579.9	0.08	5.76	1.41	6.88	46.39
Idle		----	0.8	4.27	129.8	0.067	----	0.05	0.29	8.70
2800	100	90.5	24.2	154.75	1693.0	0.08	7.24	1.94	12.38	135.44
2800	75	70.3	18.2	53.66	1334.4	0.08	5.62	1.46	4.29	106.75
2800	50	47.3	13.5	42.92	1069.3	0.08	3.78	1.08	3.43	85.54
2800	25	23.5	9.2	58.20	786.3	0.08	1.88	0.74	4.66	62.90
2800	2	2.1	5.7	40.77	387.4	0.08	0.17	0.46	3.26	30.99
Idle	---	----	0.8	4.27	129.8	0.067	----	0.05	0.29	8.70
							33.28	9.74	43.73	616.83

Brake Specific Particulate, g/kW-hr	1.314
Fuel Specific Particulate, g/kg fuel	4.490
Brake Specific $SO_4^=$, mg/kW-hr	18.54
Fuel Specific $SO_4^=$, mg/kg fuel	63.33

TABLE D-75. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
DAIMLER-BENZ OM-352 NATURALLY ASPIRATED ENGINE
(13-MODE FTP WEIGHTING FACTORS) RUN 2

							Weighted			
Engine rpm	% Load	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr	Wgt. Fact.	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr
Idle	---	----	0.8	4.19	164.1	0.067	----	0.05	0.28	11.00
2000	2	1.5	3.3	15.12	258.0	0.08	0.12	0.26	1.21	20.64
2000	25	17.9	5.9	33.04	379.8	0.08	1.43	0.47	2.64	30.38
2000	50	36.8	9.3	25.32	731.2	0.08	2.94	0.74	2.03	58.50
2000	75	54.2	12.8	31.51	582.1	0.08	4.34	1.02	2.52	46.57
2000	100	72.1	17.6	87.96	684.0	0.08	5.77	1.41	7.04	54.72
Idle		----	0.8	4.19	164.1	0.067	----	0.05	0.28	11.00
2800	100	91.8	24.7	146.68	1115.7	0.08	7.34	1.98	11.73	89.26
2800	75	70.3	18.1	51.74	1078.5	0.08	5.62	1.45	4.14	86.28
2800	50	47.3	13.5	42.37	1202.7	0.08	3.78	1.08	3.39	96.22
2800	25	23.4	9.3	65.55	1022.0	0.08	1.87	0.74	5.24	81.76
2800	2	2.1	5.6	49.60	681.6	0.08	0.17	0.45	3.97	54.53
Idle	---	----	0.8	4.19	164.0	0.067	----	0.05	0.28	11.00
							33.38	9.75	44.75	651.86

Brake Specific Particulate, g/kW-hr	1.341
Fuel Specific Particulate, g/kg fuel	4.590
Brake Specific $SO_4^=$, mg/kW-hr	19.53
Fuel Specific $SO_4^=$, mg/kg fuel	66.86

TABLE D-76. BRAKE AND FUEL SPECIFIC BaP RATE - 7-MODE CYCLE
DAIMLER-BENZ OM-352 NATURALLY ASPIRATED ENGINE

Mode	Engine rpm	Engine load, %	Power kW	Fuel kg/hr	BaP µg/hr	Org. Sol., %	Wgt. Fact.	Power kW	Fuel kg/hr	BaP µg/hr	Org. Sol., %
							W.F. Derived From 13-Mode FTP				
1	2000	2	1.5	3.4	14.99	37.34	0.12	0.18	0.41	1.80	4.48
2	2000	50	35.8	9.0	55.49	57.24	0.16	5.73	1.44	8.88	9.16
3	2000	100	71.3	17.9	BMD	7.13	0.12	8.56	2.15	-----	0.86
4	Idle	---	----	0.8	54.77	17.07	0.20	-----	0.16	10.95	3.41
5	2800	100	95.4	25.1	BMD	7.40	0.12	11.45	3.01	-----	0.89
6	2800	50	50.8	13.9	120.71	51.59	0.16	8.13	2.22	19.31	8.25
7	2800	2	2.1	5.9	66.16	59.14	0.12	0.25	0.71	7.94	7.10
								34.30	10.10	48.88	34.15

Brake Specific BaP, µg/kW-hr	1.425
Fuel Specific BaP, µg/kg fuel	4.840
Cycle Specific Organic Solubles, %	34.15

							W.F. Derived From 21-Mode EPA				
							0.225	0.34	0.77	3.37	8.40
							0.092	3.29	0.83	5.11	5.27
							0.049	3.48	0.88	-----	0.35
							0.269	-----	0.22	14.73	4.59
							0.176	16.79	4.42	-----	1.30
							0.110	5.59	1.53	13.28	5.67
							0.079	0.17	0.47	5.23	4.67
								29.66	9.12	41.72	30.25

Brake Specific BaP, µg/kW-hr	1.407
Fuel Specific BaP, µg/kg fuel	4.575
Cycle Specific Organic Solubles, %	30.25

BMD - Below Minimum Detectable

TABLE D-77. BRAKE AND FUEL SPECIFIC BaP RATE - 7-MODE CYCLE
DAIMLER-BENZ OM-352A TURBOCHARGED ENGINE

Mode	Engine rpm	Engine load, %	Power kW	Fuel kg/hr	BaP µg/hr	Org. Sol., %	Wgt. Fact.	Power kW	Fuel kg/hr	BaP µg/hr	Org. Sol., %
							W.F. Derived From 13-Mode FTP				
1	1800	2	1.3	2.9	19.86	28.86	0.12	0.16	0.35	2.38	3.46
2	1800	50	37.6	9.3	83.24	37.81	0.16	6.02	1.50	13.32	6.05
3	1800	100	72.5	16.8	-----	8.11	0.12	8.70	2.02	-----	0.97
4	Idle	---	-----	0.6	32.62	17.48	0.20	-----	0.12	6.52	3.50
5	2800	100	106.2	26.5	-----	7.70	0.12	12.74	3.18	-----	0.92
6	2800	50	54.3	15.5	96.99	39.74	0.16	8.69	2.48	15.52	6.36
7	2800	2	2.1	6.1	43.01	66.36	0.12	0.25	0.73	5.16	7.96
								36.56	10.38	42.90	29.22

Brake Specific BaP, µg/kW-hr 1.173
Fuel Specific BaP, µg/kg fuel 4.133
Cycle Specific Organic Solubles, % 29.22

Wgt. Fact.	Power kW	Fuel kg/hr	BaP µg/hr	Org. Sol., %
W.F. Derived From 21-Mode EPA				
0.225	0.29	0.65	4.47	6.49
0.092	3.46	0.86	7.66	3.48
0.049	3.55	0.82	-----	0.39
0.269	-----	0.16	8.77	4.70
0.176	18.69	4.66	-----	1.36
0.110	5.97	1.71	10.67	4.37
0.079	0.17	0.48	3.40	5.24
	32.13	9.34	34.97	26.03

Brake Specific BaP, µg/kW-hr 1.088
Fuel Specific BaP, µg/kg fuel 3.744
Cycle Specific Organic Solubles, % 26.03

TABLE D-78. METALS ANALYSIS OF FILTER-COLLECTED PARTICULATE
(PERCENT BY WEIGHT BASED ON FLUOROPORE FILTER SAMPLES)
DAIMLER-BENZ OM-352 ENGINE

Condition Speed/% Load	Configuration	Mg	Al	Si	P	S	Cl	K	Ca	Fe	Zn	Ba
Inter/02	OM-352 NA			0.01	0.04	0.62			0.06			
	OM-352 TC	0.04	0.01	0.10		0.82	0.06	0.04	0.14			
Inter/25	OM-352 NA				0.02	0.47			0.04		0.06	
	OM-352 TC					1.0			0.09			
Inter/50	OM-352 NA		0.01	0.07	0.07	0.91			0.27			
	OM-352 TC				0.08	1.4			0.11			
Inter/75	OM-352 NA				0.18	1.5			0.39			
	OM-352 TC				0.06	1.4			0.13			
Inter/100	OM-352 NA				0.08	0.44	0.04		0.23		0.10	
	OM-352 TC				0.05	1.0			0.11			
Idle	OM-352 NA			0.05		1.4			0.07			
	OM-352 TC					1.0						
High/100	OM-352 NA		0.002	0.01	0.27	0.67	0.06		0.94	0.04	0.32	0.04
	OM-352 TC	No Data										
High/75	OM-352 NA				0.51	1.7	0.04		1.2		0.69	0.06
	OM-352 TC				0.17	1.3			0.39			
High/50	OM-352 NA		0.01	0.03	0.24	1.3			0.49		0.31	
	OM-352 TC				0.14	1.3			0.25		0.17	
High/25	OM-352 NA			0.01	0.07	0.49			0.12		0.09	
	OM-352 TC				0.06	0.56			0.11			
High/02	OM-352 NA					0.49			0.09			
	OM-352 TC			0.03		0.52			0.10			

TABLE D-79. PERCENT PER STAGE OF TOTAL PARTICULATE COLLECTED BY ANDERSON IMPACTOR FOR DAIMLER-BENZ OM-352 NA AND OM-352A TC

Stage No.	ECD, micron	Intermediate Speed[1] 2%	50%	100%	Idle	2800 rpm 100%	50%	2%
				OM-352 Naturally Aspirated				
1	10.9	0.61	0.41	0.59	0.54	0.60	0.48	0.76
2	6.8	0.47	0.54	0.80	0.63	0.92	0.60	0.31
3	4.6	0.36	0.81	1.8	0.49	3.2	1.9	0.67
4	3.2	0.18	1.2	2.1	0.83	3.8	1.3	0.90
5	2.0	0.29	1.7	2.7	0.39	4.3	2.0	0.81
6	1.03	0.83	1.4	3.5	0.92	6.2	2.5	0.90
7	0.63	1.2	1.9	3.4	1.2	5.5	2.5	1.0
8	0.42	1.6	2.1	3.5	3.9	4.0	3.3	1.9
Filter	<0.42	94.5	90.0	81.5	91.0	71.3	85.3	92.7
				OM-352A Turbocharged				
1	10.9	0.83	0.44	0.52	0.28	0.59	0.20	0.16
2	6.8	1.5	0.55	0.40	0.28	1.4	0.59	0.31
3	4.6	0.61	0.55	0.57	0.17	2.4	0.47	0.39
4	3.2	0.67	0.85	1.2	0.45	2.3	0.26	0.49
5	2.0	1.2	0.55	1.8	0.48	3.5	0.68	0.49
6	1.03	2.3	1.8	1.6	0.41	3.7	1.9	0.65
7	0.63	1.4	3.0	2.9	1.1	6.9	2.5	1.0
8	0.42	2.8	4.2	3.4	4.2	5.3	5.3	0.47
Filter	<0.42	88.7	88.0	87.7	92.6	74.0	88.1	96.0

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(1) 2000 rpm OM-352, 1800 rpm OM-352A

TABLE D-80. ALDEHYDES BY DNPH FOR DAIMLER-BENZ OM-352 NATURALLY ASPIRATED ENGINE

		2000 rpm				2800 rpm		
Aldehyde	Rate	2	50	100	Idle	100	50	2
Form-aldehyde	μg/m^3	11885	1570	1626	16642	985	9431	14997
	mg/hr	4830	644	664	1996	544	5248	8133
	mg/kg fuel	1420	71	38	2445	22	399	1379
	mg/kW-hr	3220	18	9	---	6	114	3873
Acet-aldehyde	μg/m^3	4035	378	586	4067	0	1911	3481
	mg/hr	3545	335	517	1054	0	2298	4079
	mg/kg fuel	1042	37	29	1291	0	175	692
	mg/kW-hr	2363	9	7	---	0	50	1943
Acetone	μg/m^3	1886	0	0	1959	0	208	1050
	mg/hr	2847	0	0	873	0	430	2114
	mg/kg fuel	837	0	0	1069	0	33	359
	mg/kW-hr	1898	0	0	---	0	9	1007
Iso-butyr-aldehyde	μg/m^3	815	31	0	745	0	326	559
	mg/hr	1903	73	0	514	0	1042	1741
	mg/kg fuel	559	8	0	629	0	79	295
	mg/kW-hr	1269	2	0	---	0	23	829
Crotonal	μg/m^3	1012	103	274	948	298	544	774
	mg/hr	2247	231	611	622	899	1653	2293
	mg/kg fuel	660	25	35	761	36	126	389
	mg/kW-hr	1498	6	8	---	10	36	1092
Hexanal	μg/m^3	314	78	0	211	161	225	308
	mg/hr	1422	356	0	282	993	1396	1864
	mg/kg fuel	418	39	0	346	40	106	316
	mg/kW-hr	948	10	0	---	11	30	888
Benz-aldehyde	μg/m^3	1017	598	872	1238	356	975	1046
	mg/hr	5150	3056	4437	1851	2449	6759	7068
	mg/kg fuel	1514	337	251	2267	99	514	1199
	mg/kW-hr	3434	85	62	---	27	147	3366

TABLE D-81. ALDEHYDES BY DNPH FOR DAIMLER-BENZ OM-352A TURBOCHARGED ENGINE

Aldehyde	Rate	1800 rpm				2800 rpm		
		2	50	100	Idle	100	50	2
Formaldehyde	$\mu g/m^3$	4525	1610	2369	13957	11931	5770	15927
	mg/hr	1646	669	1230	1775	9954	3905	8862
	mg/kg fuel	568	72	71	2541	373	252	1477
	mg/kW-hr	1266	18	16	---	92	72	4923
Acetaldehyde	$\mu g/m^3$	2207	303	731	8828	2163	1759	2661
	mg/hr	1735	272	820	2427	3900	2573	3200
	mg/kg fuel	599	29	47	3474	146	166	533
	mg/kW-hr	1335	7	11	---	36	47	1778
Acetone	$\mu g/m^3$	411	---	358	2138	---	213	2999
	mg/hr	555	---	690	1010	---	535	6198
	mg/kg fuel	192	---	40	1446	---	35	1033
	mg/kW-hr	427	---	9	---	---	10	3443
Isobutanal	$\mu g/m^3$	322	---	---	450	---	---	741
	mg/hr	673	---	---	329	---	---	2370
	mg/kg fuel	232	---	---	471	---	---	395
	mg/kW-hr	518	---	---	---	---	---	1317
Crotonal	$\mu g/m^3$	---	---	---	920	357	---	2829
	mg/hr	---	---	---	640	1628	---	8602
	mg/kg fuel	---	---	---	916	61	---	1433
	mg/kW-hr	---	---	---	---	15	---	4779
Hexanal	$\mu g/m^3$	167	72	89	450	125	239	453
	mg/hr	676	335	514	638	1163	1803	2809
	mg/kg fuel	233	36	30	914	44	116	468
	mg/kW-hr	520	9	7	---	11	33	1561
Benzaldehyde	$\mu g/m^3$	---	453	561	751	1310	379	999
	mg/hr	---	2347	3629	1190	13614	3199	6924
	mg/kg fuel	---	252	209	1704	510	206	1154
	mg/kW-hr	---	62	47	---	126	59	3847

TABLE D-82. SPECIFIC HYDROCARBON EMISSION RATES, DAIMLER-BENZ OM-352 NATURALLY ASPIRATED ENGINE

		2000 rpm				2800 rpm		
Hydrocarbon	Rate	2	50	100	Idle	100	50	2
Methane	µg/m^3	3863	2464	5594	4262	499	2930	4528
CH_4	mg/hr	1171	754	1704	381	206	1216	1832
	mg/kg fuel	344	83	96	467	8	92	311
	mg/kW-hr	780	21	24	---	2	27	872
Ethylene	µg/m^3	21440	20275	54708	18353	1340	25985	27034
C_2H_4	mg/hr	6499	6201	16660	1642	552	10783	10934
	mg/kg fuel	1910	684	942	2011	22	820	1854
	mg/kW-hr	4333	173	231	---	6	235	5207
Ethane	µg/m^3	387	325	400	518	0	512	462
C_2H_6	mg/hr	117	99	122	46	0	213	187
	mg/kg fuel	35	11	7	57	0	16	32
	mg/kW-hr	78	3	2	---	0	5	89
Acetylene	µg/m^3	2057	1786	5846	1895	1191	2761	2652
C_2H_2	mg/hr	623	546	1778	169	490	1144	1072
	mg/kg fuel	183	60	101	207	20	87	182
	mg/kw-hr	415	15	25	---	5	25	510
Propane	µg/m^3	58	58	0	98	0	58	58
C_3H_8	mg/hr	19	19	0	9	0	25	25
	mg/kg fuel	5	2	0	11	0	2	4
	mg/kW-hr	12	1	0	---	0	1	12
Propylene	µg/m^3	7982	8157	7574	6700	0	9555	10196
C_3H_6	mg/hr	2420	2495	2307	599	0	3965	4124
	mg/kg fuel	711	275	130	734	0	301	699
	mg/kW-hr	1613	70	32	---	0	86	1964
Benzene	µg/m^3	2247	1966	6292	2359	404	1966	1966
C_6H_6	mg/hr	656	579	1844	203	160	785	765
	mg/kg fuel	193	64	104	249	6	60	130
	mg/kW-hr	437	16	26	---	2	17	364
Toluene	µg/m^3	2685	1260	471	1370	203	932	1206
C_7H_8	mg/hr	812	384	143	122	83	386	486
	mg/kg fuel	239	42	8	150	3	29	82
	mg/kW-hr	541	11	2	---	1	8	232

TABLE D-83. SPECIFIC HYDROCARBON EMISSION RATES, DAIMLER-BENZ OM-352A TURBOCHARGED ENGINE

		1800 rpm				2800 rpm		
Hydrocarbon	Rate	2	50	100	Idle	100	50	2
Methane	$\mu g/m^3$	3796	1598	1332	4262	1998	1931	4395
CH_4	mg/hr	1030	496	516	404	1244	975	1825
	mg/kg fuel	355	53	30	579	47	63	304
	mg/kW-hr	792	13	7	---	11	18	1014
Ethylene	$\mu g/m^3$	22314	10312	24645	23072	48416	22140	29830
C_2H_4	mg/hr	6053	3197	9540	2189	30129	11175	12380
	mg/kg fuel	2088	344	548	3133	1128	721	2063
	mg/kW-hr	4657	84	125	---	278	206	6878
Ethane	$\mu g/m^3$	375	187	312	499	499	375	375
C_2H_6	mg/hr	102	58	121	47	311	189	156
	mg/kg fuel	35	6	7	68	12	12	26
	mg/kW-hr	78	2	2	---	3	3	86
Acetylene	$\mu g/m^3$	1678	812	758	1949	2490	1407	2273
C_2H_2	mg/hr	455	251	293	185	1548	710	942
	mg/kg fuel	157	27	17	264	58	46	157
	mg/kW-hr	350	7	4	---	14	13	524
Propane	$\mu g/m^3$	---	---	---	115	---	---	---
C_3H_8	mg/hr	---	---	---	12	---	---	---
	mg/kg fuel	---	---	---	17	---	---	---
	mg/kW-hr	---	---	---	---	---	---	---
Propylene	$\mu g/m^3$	7924	4078	11944	8215	16546	10079	11012
C_3H_6	mg/hr	2150	1264	4623	779	10297	5087	4570
	mg/kg fuel	742	136	266	1116	386	328	762
	mg/kW-hr	1653	33	60	---	95	94	2539
Benzene	$\mu g/m^3$	2022	1067	2135	3034	3034	2022	3202
C_6H_6	mg/hr	528	318	795	277	2793	982	1279
	mg/kg fuel	182	34	46	396	105	63	213
	mg/kW-hr	406	8	10	---	26	18	711
Toluene	$\mu g/m^3$	384	329	877	1041	1754	712	986
C_7H_8	mg/hr	104	102	338	99	1088	359	408
	mg/kg fuel	36	11	19	141	41	23	68
	mg/kW-hr	80	3	4	---	10	7	227

TABLE D-84. 13-MODE FEDERAL DIESEL EMISSION CYCLE

MACK-ETAY673+APS (HIGH PRESSURE PUMP) CONFIGURATION S/N 6F4310
TEST 1 RUN 1 5-15-78 FUEL EM-329-F PROJECT 11-4623-001

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	750	0.0	0.0	.033	4.72	4.75	.007
2	1450	59.3	9.0	.080	9.41	9.49	.009
3	1450	389.3	59.1	.224	10.42	10.65	.021
4	1450	773.9	117.5	.419	13.39	13.81	.031
5	1450	1163.2	176.6	.609	17.01	17.62	.036
6	1450	1538.3	233.6	.818	19.91	20.73	.041
7	750	0.0	0.0	.030	4.06	4.09	.007
8	1900	1234.4	245.6	.921	26.80	27.72	.034
9	1900	928.2	184.7	.707	23.05	23.76	.031
10	1900	617.2	122.8	.488	18.65	19.13	.026
11	1900	308.6	61.4	.280	14.89	15.17	.019
12	1900	68.8	13.7	.138	12.35	12.49	.011
13	750	0.0	0.0	.030	3.99	4.02	.008

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	200	235	235	0.00	R	R	R	11.6
2	360	433	156	.72	11.04	26.46	15.64	11.6
3	244	172	673	4.73	1.28	1.80	11.56	10.9
4	192	113	1084	9.40	.66	.77	12.14	10.9
5	112	140	1272	14.13	.33	.81	12.09	10.9
6	66	274	1420	18.68	.17	1.41	12.00	10.5
7	192	177	320	0.00	R	R	R	10.5
8	56	140	1123	19.65	.18	.92	12.07	10.5
9	104	114	934	14.77	.39	.85	11.45	10.0
10	136	115	736	9.82	.62	1.04	10.92	10.0
11	220	202	479	4.91	1.58	2.89	11.27	10.0
12	424	460	203	1.10	11.25	24.34	17.60	9.4
13	196	236	351	0.00	R	R	R	9.4

CYCLE COMPOSITE BSHC = .699 GRAM/KW HR
BSCO+ = 1.685 GRAM/KW HR
BSNO2++= 12.130 GRAM/KW HR
BSHC + BSNO2++= 12.829 GRAM/KW HR
BSFC = .233KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE D-85. 13-MODE FEDERAL DIESEL EMISSION CYCLE

MACK-ETAY 673A +APS (HIGH PRESSURE PUMP) CONFIGURATION S/N 6F4310
TEST 2 RUN1 5-15-78 FUEL EM-329-F PROJECT 11-4623-001

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	750	0.0	0.0	.026	3,98	4.01	.006
2	1450	54,6	8.3	.079	9,43	9.51	.008
3	1450	389.3	59.1	.233	10,67	10.90	.022
4	1450	769.1	116.8	.417	12,91	13.32	.032
5	1450	1151,3	174.8	.612	16,78	17.40	.036
6	1450	1531.2	232.5	.818	19,64	20.46	.042
7	750	0,0	0.0	.029	4,71	4,74	.006
8	1900	1239.2	246.5	.924	26,73	27,65	.035
9	1900	925.8	184,2	.703	22,81	23,51	.031
10	1900	617.2	122.8	.488	18,06	18.55	.027
11	1900	311.0	61,9	.281	14,88	15.16	.019
12	1900	66,5	13,2	.138	12,63	12,77	.011
13	750	0.0	0.0	.030	4,24	4,27	.007

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM, MILL G/K
1	216	177	217	0,00	R	R	R	11,0
2	384	406	168	,66	12,82	26,98	18,40	11,0
3	244	172	684	4,73	1,31	1,84	12.01	11,0
4	184	113	1074	9,34	.61	.75	11.68	11,0
5	116	139	1331	13,98	,34	,80	12,62	11,0
6	48	246	1469	18,60	.12	1,26	12.31	10,7
7	200	178	288	0.00	R	R	R	10,7
8	50	168	1061	19,72	,16	1,09	11.33	10,7
9	90	114	919	14,74	.33	.84	11,17	10,5
10	136	114	737	9,82	.60	1,00	10.60	10,5
11	200	201	457	4,95	1,43	2,86	10,67	10,5
12	416	457	200	1,06	11,69	25,57	18,41	10,5
13	204	235	322	0,00	R	R	R	10,5

CYCLE COMPOSITE BSHC = ,677 GRAM/KW HR
BSCO+ = 1,671 GRAM/KW HR
BSNO2++= 11,997 GRAM/KW HR
BSHC + BSNO2++= 12,674 GRAM/KW HR
BSFC = ,234KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE D-86. 21-MODE EPA EXP DIESEL EMISSION CYCLE

MACK-ETAY673A+APS (HIGH PRESSURE PUMP) CONFIGURATION S/N 6F4310
TEST 1 RUN 1 5-15-78 FUEL EM-329-F PROJECT 11-4623-001

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO
1	750	0.0	0.0	.033	4.72	4.75	.007
2	1450	59.3	9.0	.080	9.41	9.49	.009
3	1450	125.8	19.1	.112	9.47	9.58	.012
4	1450	280.1	42.5	.178	9.76	9.94	.018
5	1450	389.3	59.1	.224	10.42	10.65	.021
6	1450	773.9	117.5	.419	13.39	13.81	.031
7	1450	1163.2	176.6	.609	17.01	17.62	.036
8	1450	1270.0	192.8	.665	17.77	18.43	.037
9	1450	1429.1	217.0	.759	19.49	20.25	.039
10	1450	1538.3	233.6	.818	19.91	20.73	.041
11	750	0.0	0.0	.030	4.06	4.09	.007
12	1900	1234.4	245.6	.921	26.80	27.72	.034
13	1900	1134.7	225.7	.839	25.89	26.73	.032
14	1900	1011.3	201.2	.758	24.39	25.15	.031
15	1900	928.2	184.7	.707	23.05	23.76	.031
16	1900	617.2	122.8	.488	18.65	19.13	.026
17	1900	308.6	61.4	.280	14.89	15.17	.019
18	1900	220.8	43.9	.227	14.10	14.33	.016
19	1900	102.1	20.3	.165	12.93	13.10	.013
20	1900	68.8	13.7	.138	12.35	12.49	.011
21	750	0.0	0.0	.030	3.99	4.02	.008

MODE	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	200	235	239	0.00	R	R	R	11.6
2	360	433	196	.66	11.04	26.46	19.68	11.6
3	312	375	324	1.39	4.55	10.90	15.48	11.6
4	260	230	602	2.59	1.77	3.11	13.40	11.6
5	244	172	738	2.13	1.28	1.80	12.66	10.9
6	192	113	1097	8.58	.66	.77	12.27	10.9
7	112	140	1300	0.00	I	I	I	10.9
8	108	276	1327	9.45	.30	1.53	12.08	10.9
9	76	248	1380	0.00	I	I	I	10.5
10	66	274	1427	0.00	I	I	I	10.5
11	192	177	339	0.00	R	R	R	10.5
12	56	140	1008	7.86	.18	.92	10.83	10.5
13	82	141	980	15.13	.28	.97	11.05	10.5
14	114	114	905	8.65	.41	.82	10.77	9.8
15	104	114	874	13.48	.39	.85	10.71	10.0
16	136	115	667	8.96	.62	1.04	9.90	10.0
17	220	202	422	0.00	I	I	I	10.0
18	304	260	375	3.47	2.89	4.92	11.65	9.4
19	372	403	229	0.00	I	I	I	9.4
20	424	460	196	0.00	I	I	I	9.4
21	196	236	327	0.00	R	R	R	9.4

CYCLE COMPOSITE BSHC = .802 GRAM/KW HR
BSCO+ = 1.782 GRAM/KW HR
BSNO2++= 11.745 GRAM/KW HR
BSHC + BSNO2++= 12.547 GRAM/KW HR
BSFC = .239KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE D-87. 21-MODE EPA EXP DIESEL EMISSION CYCLE

MACK-ETAY 673A + APS (HIGH PRESSURE PUMP) CONFIGURATION S/N 6F4310
TEST 2 RUN1 5-15-78 FUEL EM-329-F PROJECT

MODE	ENGINE SPEED RPM	TORQUE N X M	POWER KW	FUEL FLOW KG/MIN	AIR FLOW KG/MIN	EXHAUST FLOW KG/MIN	FUEL AIR RATIO	HC PPM	CO+ PPM	NO++ PPM	WEIGHTED KW	BSHC G/KW HR	BSCO+ G/KW HR	BSNO2++ G/KW HR	HUM. MILLI G/KG
1	750	0.0	0.0	.026	3.98	4.01	.006	216	177	254	0.00	R	R	R	11.0
2	1450	54.6	8.3	.079	9.43	9.51	.008	384	406	199	.61	12.82	26.98	21.74	11.0
3	1450	121.1	18.4	.110	9.27	9.38	.012	308	347	300	1.34	4.58	10.28	14.59	11.0
4	1450	275.4	41.8	.174	9.84	10.01	.018	272	202	563	2.55	1.90	2.80	12.84	11.0
5	1450	389.3	59.1	.233	10.67	10.90	.022	244	172	680	2.13	1.31	1.84	11.94	11.0
6	1450	769.1	116.8	.417	12.91	13.32	.032	184	113	1104	8.52	.61	.75	11.99	11.0
7	1450	1151.3	174.8	.612	16.78	17.40	.036	116	139	1238	0.00	I	I	I	11.0
8	1450	1262.9	191.7	.665	17.39	18.06	.038	88	194	1283	9.40	.24	1.06	11.51	10.7
9	1450	1412.5	214.5	.756	18.76	19.52	.040	58	220	1332	0.00	I	I	I	10.7
10	1450	1531.2	232.5	.818	19.64	20.46	.042	48	246	1371	0.00	I	I	I	10.7
11	750	0.0	0.0	.029	4.71	4.74	.006	200	178	305	0.00	R	R	R	10.7
12	1900	1239.2	246.5	.924	26.73	27.65	.035	50	168	997	7.89	.16	1.09	10.65	10.7
13	1900	1134.7	225.7	.845	25.62	26.46	.033	64	168	990	15.13	.22	1.14	11.05	10.7
14	1900	1011.3	201.2	.754	24.11	24.86	.031	108	141	937	8.65	.39	1.01	11.03	10.7
15	1900	925.8	184.2	.703	22.81	23.51	.031	90	114	876	13.45	.33	.84	10.66	10.5
16	1900	617.2	122.8	.488	18.06	18.55	.027	136	114	696	8.96	.60	1.00	10.01	10.5
17	1900	311.0	61.9	.281	14.88	15.16	.019	200	201	421	0.00	I	I	I	10.5
18	1900	225.5	44.9	.236	13.79	14.02	.017	276	259	357	3.54	2.51	4.70	10.62	10.5
19	1900	97.3	19.4	.162	12.96	13.12	.012	364	403	235	0.00	I	I	I	10.5
20	1900	66.5	13.2	.138	12.63	12.77	.011	416	457	200	0.00	I	I	I	10.5
21	750	0.0	0.0	.030	4.24	4.27	.007	204	235	313	0.00	R	R	R	10.5

CYCLE COMPOSITE BSHC = .763 GRAM/KW HR
BSCO+ = 1.733 GRAM/KW HR
BSNO2++= 11.574 GRAM/KW HR
BSHC + BSNO2++= 12.337 GRAM/KW HR
BSFC = .239KG/KW HR

+ CONVERTED TO WET BASIS
++ CONVERTED TO WET BASIS AND CORRECTED TO 10.7 MILLIGRAMS WATER PER KG DRY AIR

TABLE D-88. SUMMARY OF EXHAUST PARTICULATE FROM MACK ETAY(B)673A WITH A. BOSCH APS SYSTEM (BASED ON 47-mm GLASSFIBER FILTERS)

Engine rpm/% load	Run No.	Concentration mg/m^3	Particulate Rate g/hr	Particulate Rate g/kg fuel	Particulate Rate g/kW-hr
1450/2	1	60.70	27.36	5.70	3.30
	2	64.31	29.10	6.06	3.51
	Avg	62.51	28.23	5.88	3.41
1450/25	1	35.62	18.86	1.39	0.32
	2	38.24	20.29	1.47	0.34
	Avg	36.93	19.58	1.43	0.33
1450/50	1	60.84	41.53	1.67	0.35
	2	61.82	42.08	1.68	0.36
	Avg	61.33	41.81	1.68	0.36
1450/75	1	69.43	59.85	1.62	0.34
	2	66.45	57.67	1.55	0.33
	Avg	67.94	58.76	1.59	0.34
1450/100	1	70.24	72.70	1.48	0.31
	2	69.69	72.22	1.47	0.31
	Avg	69.97	72.46	1.48	0.31
Idle	1	34.26	6.58	5.98	----
	2	46.66	8.82	8.02	----
	Avg	40.46	7.70	7.00	----
1900/100	1	65.86	88.18	1.59	0.37
	2	64.49	86.99	1.57	0.36
	Avg	65.18	87.59	1.58	0.37
1900/75	1	38.52	44.80	1.07	0.24
	2	38.65	45.13	1.08	0.24
	Avg	38.59	44.97	1.08	0.24
1900/50	1	43.21	40.14	1.41	0.33
	2	45.32	38.32	1.34	0.31
	Avg	44.27	39.23	1.38	0.32
1900/25	1	53.01	39.18	2.39	0.64
	2	48.46	35.65	2.12	0.58
	Avg	50.74	37.42	2.26	0.61
1900/2	1	55.64	34.07	5.01	5.98
	2	58.95	36.16	5.24	6.95
	Avg	57.30	35.12	5.13	6.47

TABLE D-89. SUMMARY OF EXHAUST $SO_4^=$ FROM MACK ETAY(B)673A WITH A. BOSCH APS SYSTEM (BASED ON 47 mm FLUOROPORE FILTERS)

Engine rpm/% load	Run No.	Concentration μg/m³	Sulfate Rate			$SO_4^=$ as % Fuel S
			mg/hr	mg/kg fuel	mg/kW-hr	
1450/2	1	1121.25	507.23	105.67	61.86	1.46
	2	1164.99	522.80	108.92	62.99	1.51
	Avg	1143.12	515.02	107.30	62.43	1.49
1450/25	1	3287.24	1740.35	127.97	29.45	1.77
	2	3826.07	2029.71	148.15	34.34	2.05
	Avg	3556.66	1885.03	138.06	31.90	1.91
1450/50	1	8180.14	5487.12	221.25	46.42	3.07
	2	6728.50	4581.55	183.26	38.76	2.54
	Avg	7454.32	5034.34	202.26	42.59	2.81
1450/75	1	8755.39	7580.28	204.87	42.83	2.84
	2	7028.26	6099.28	164.40	34.46	2.28
	Avg	7891.83	6839.78	184.64	38.65	2.56
1450/100	1	5974.49	6183.79	125.43	26.24	1.74
	2	7496.67	7767.44	158.20	32.95	2.19
	Avg	6735.58	6975.62	141.82	29.60	1.97
Idle	1	1082.03	207.23	172.69	-----	2.39
	2	1188.25	221.43	221.43	-----	3.07
	Avg	1135.14	214.33	197.06	-----	2.73
1900/100	1	9421.21	12655.80	228.43	52.02	3.17
	2	9824.64	13154.44	227.87	54.70	3.16
	Avg	9622.93	12905.12	228.15	53.36	3.17
1900/75	1	6225.43	7240.26	173.63	39.20	2.41
	2	6387.46	7758.28	185.60	42.00	2.57
	Avg	6306.45	7499.27	179.62	40.60	2.49
1900/50	1	6643.55	6170.25	216.50	50.25	3.00
	2	6727.37	5688.40	198.20	46.32	2.75
		6685.46	5929.33	207.35	48.29	2.88
1900/25	1	4024.33	2974.43	180.27	48.44	2.50
	2	3946.40	2904.10	173.90	47.30	2.41
	Avg	3985.37	2939.27	177.09	47.87	2.46
1900/2	1	1294.43	793.85	113.41	152.66	1.57
	2	1454.94	898.43	130.21	172.78	1.80
	Avg	1374.69	846.14	121.81	162.72	1.69

TABLE D-90. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
MACK ETAY(B)673A WITH A. BOSCH APS SYSTEM
(13-MODE FTP WEIGHTING FACTORS), RUN 1

						Weighted			
Engine rpm/% load	Power kW	Fuel kg/hr	Particulate g/hr	$SO_4^=$ mg/hr	Wgt. Fact	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr
Idle	--	1.1	6.58	207.23	0.067	--	0.07	0.44	13.88
1450/2	8.2	4.8	27.36	507.23	0.08	0.66	0.38	2.19	40.58
1450/25	59.1	13.6	18.86	1740.35	0.08	4.73	1.09	1.51	139.23
1450/50	118.2	24.9	41.53	5487.12	0.08	9.46	1.99	3.32	438.97
1450/75	177.0	37.0	59.85	7580.28	0.08	14.16	2.96	4.79	606.42
1450/100	235.7	49.0	72.70	6183.79	0.08	18.86	3.92	5.82	494.70
Idle	--	1.1	6.58	207.23	0.067	--	0.07	0.44	13.88
1900/100	240.5	55.3	88.18	12655.8	0.08	19.24	4.42	7.05	1012.46
1900/75	184.7	41.7	44.80	7240.26	0.08	14.78	3.34	3.58	579.22
1900/50	122.8	28.5	40.14	6170.25	0.08	9.82	2.28	3.21	493.62
1900/25	61.4	16.4	39.18	2974.43	0.08	4.91	1.31	3.13	237.95
1900/2	5.7	6.8	34.07	793.85	0.08	0.46	0.54	2.73	63.51
Idle	--	1.1	6.58	207.23	0.067	--	0.07	0.44	13.88
						97.08	22.44	38.65	4148.30

Brake Specific Particulate, g/kW-hr	0.398
Fuel Specific Particulate, g/kg fuel	1.722
Brake Specific $SO_4^=$, mg/kW-hr	42.73
Fuel Specific $SO_4^=$, mg/kg fuel	184.86

TABLE D-91. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES
MACK ETAY(B)673A WITH A. BOSCH APS SYSTEM
(13-MODE FTP WEIGHTING FACTORS), RUN 2

						Weighted			
Engine rpm/% load	Power kW	Fuel kg/hr	Particulate g/hr	$SO_4^=$ mg/hr	Wgt. Fact	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr
Idle	--	1.1	8.82	221.43	0.067	--	0.07	0.59	14.84
1450/2	8.2	4.8	29.10	522.80	0.08	0.66	0.38	2.33	41.82
1450/25	59.1	13.8	20.29	2029.71	0.08	4.73	1.10	1.62	162.38
1450/50	118.2	25.0	42.08	4581.55	0.08	9.46	2.00	3.37	366.52
1450/75	177.0	37.1	57.67	6099.28	0.08	14.16	2.97	4.61	487.94
1450/100	235.7	49.0	72.22	7767.44	0.08	18.86	3.92	5.78	621.40
Idle	--	1.1	8.82	221.43	0.067	--	0.07	0.59	14.84
1900/100	241.0	55.3	86.99	13154.44	0.08	19.28	4.42	6.96	1052.36
1900/75	184.7	41.8	45.13	7758.28	0.08	14.78	3.34	3.61	620.66
1900/50	122.8	28.7	38.32	5688.40	0.08	9.82	2.30	3.07	455.07
1900/25	61.4	16.8	35.65	2904.10	0.08	4.91	1.34	2.85	232.33
1900/2	5.2	6.9	36.16	898.43	0.08	0.42	0.55	2.89	71.87
Idle	--	1.1	8.82	221.43	0.067	--	0.07	0.59	14.84
						97.08	22.53	38.86	4156.87

Brake Specific Particulate, g/kW-hr	0.400
Fuel Specific Particulate, g/kg fuel	1.725
Brake Specific $SO_4^=$, mg/kW-hr	42.82
Fuel Specific $SO_4^=$, mg/kg fuel	184.50

TABLE D-92. SUMMARY OF EXHAUST PARTICULATE FROM MACK ETAY(B)673A WITH STANDARD R. BOSCH SYSTEM - NEW (BASED ON 47-mm GLASSFIBER FILTERS)

Engine rpm/% load	Run No.	Concentration mg/m^3	Particulate Rate		
			g/hr	g/kg fuel	g/kW-hr
1450/2	1	37.16	17.22	4.42	4.00
	2	32.75	15.25	3.91	3.55
	Avg	34.96	16.24	4.17	3.78
1450/25	1	56.17	30.44	2.36	0.56
	2	64.32	34.88	2.68	0.64
	Avg	60.25	32.66	2.52	0.60
1450/50	1	116.66	80.54	3.44	0.75
	2	123.91	84.27	3.56	0.78
	Avg	120.29	82.41	3.50	0.77
1450/75	1	163.08	142.05	4.00	0.88
	2	156.08	136.10	3.85	0.84
	Avg	159.59	139.08	3.93	0.86
1450/100	1	271.72	272.95	5.83	1.26
	2	285.07	285.17	6.08	1.32
	Avg	278.40	279.06	5.96	1.29
Idle	1	44.46	8.72	6.71	----
	2	43.24	8.50	6.07	----
	Avg	43.85	8.61	6.39	----
1900/100	1	140.61	192.75	3.48	0.81
	2	144.79	198.71	3.59	0.83
	Avg	142.70	195.73	3.54	0.82
1900/75	1	86.29	102.55	2.47	0.57
	2	87.14	104.26	2.51	0.58
	Avg	86.72	103.41	2.49	0.58
1900/50	1	87.44	83.38	2.94	0.70
	2	85.61	81.61	2.88	0.69
	Avg	86.53	82.50	2.91	0.70
1900/25	1	62.83	47.88	2.80	0.78
	2	64.65	49.30	2.88	0.80
	Avg	63.74	48.60	2.84	0.79
1900/2	1	41.60	25.55	3.81	5.94
	2	47.98	29.45	4.33	6.85
	Avg	44.79	27.50	4.07	6.40

TABLE D-93. SUMMARY OF EXHAUST $SO_4^=$ FROM MACK ETAY(B)673A WITH STANDARD R. BOSCH SYSTEM - NEW (BASED ON 47-mm FLUOROPORE FILTERS)

Engine rpm/% load	Run No.	Concentration µg/m^3	Sulfate Rate			$SO_4^=$ as % Fuel S
			mg/hr	mg/kg fuel	mg/kW-hr	
1450/2	1	712.3	331.6	85.0	77.1	1.18
	2	921.6	424.4	108.8	98.7	1.51
	Avg	817.0	378.0	96.9	87.9	1.35
1450/25	1	4194.8	2287.5	177.3	42.3	2.46
	2	4098.7	2206.1	173.7	40.8	2.41
	Avg	4146.8	2246.8	175.5	41.6	2.44
1450/50	1	5737.5	3960.7	169.3	36.6	2.35
	2	5875.9	3996.1	168.6	37.0	2.34
	Avg	5806.7	3978.4	169.0	36.8	2.34
1450/75	1	7775.7	6772.6	190.8	41.8	2.64
	2	7590.3	6636.2	186.9	40.9	2.59
	Avg	7683.0	6704.4	188.9	41.4	2.62
1450/100	1	10861.3	10865.1	231.7	50.2	3.21
	2	10403.5	10386.5	221.5	48.0	3.07
	Avg	10632.4	10625.8	226.6	49.1	3.14
Idle 650 rpm	1	1546.6	303.8	217.0	----	3.01
	2	1657.0	326.0	232.9	----	3.23
	Avg	1601.8	314.9	225.0	----	3.12
1900/100	1	9657.7	13239.7	239.0	55.4	3.31
	2	11411.4	15661.0	282.7	65.5	3.92
	Avg	10534.6	14450.4	260.9	60.5	3.62
1900/75	1	6209.4	7405.3	178.9	41.5	2.48
	2	6613.2	7937.6	191.3	44.5	2.65
	Avg	6411.3	7671.5	185.1	43.0	2.57
1900/50	1	5965.1	5667.8	201.0	47.6	2.79
	2	6295.8	6025.2	213.7	50.6	2.96
	Avg	6130.5	5846.5	207.4	49.1	2.88
1900/25	1	3434.6	2619.3	153.2	42.7	2.12
	2	3542.3	2703.9	158.1	44.0	2.19
	Avg	3488.5	2661.6	155.7	43.4	2.16
1900/2	1	1203.1	738.3	171.7	108.6	2.38
	2	1368.1	838.3	195.0	125.1	2.70
	Avg	1285.6	788.3	183.4	116.9	2.54

TABLE D-94. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES MACK ETAY(B)673A WITH STANDARD R BOSCH SYSTEM (13-MODE FTP WEIGHTING FACTORS), RUN 1

						Weighted			
Engine rpm/% load	Power kW	Fuel kg/hr	Particulate g/hr	$SO_4^=$ mg/hr	Wgt. Fact	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr
Idle	--	1.3	8.72	303.8	0.067	--	0.09	0.58	20.35
1450/2	4.3	3.9	17.22	331.6	0.08	0.34	0.31	1.38	26.53
1450/25	54.1	12.8	30.44	2287.5	0.08	4.33	1.02	2.44	183.00
1450/50	108.1	23.4	80.54	3960.7	0.08	8.65	1.87	6.44	316.86
1450/75	162.2	35.6	142.05	6772.6	0.08	12.98	2.85	11.36	514.81
1450/100	216.3	46.9	272.95	10865.1	0.08	17.30	3.75	21.84	869.21
Idle	--	1.3	8.72	303.8	0.067	--	0.09	0.58	20.35
1900/100	239.0	55.4	192.75	13239.7	0.08	19.12	4.43	15.42	1059.18
1900/75	178.8	41.5	102.55	7405.3	0.08	14.30	3.32	8.20	592.42
1900/50	119.0	28.4	83.38	5667.8	0.08	9.52	2.27	6.67	453.42
1900/25	61.4	17.1	47.88	2619.3	0.08	4.91	1.37	3.83	209.54
1900/2	4.3	6.7	25.55	738.3	0.08	0.34	0.54	2.04	59.06
Idle	--	1.3	8.72	303.8	0.067	--	0.09	0.58	20.35
						91.79	22.00	81.36	4345.08

Brake Specific Particulate, g/kW-hr	0.886
Fuel Specific Particulate, g/kg fuel	3.698
Brake Specific $SO_4^=$, mg/kW-hr	47.337
Fuel Specific $SO_4^=$, mg/kg fuel	197.504

TABLE D-95. CYCLE COMPOSITE PARTICULATE AND SULFATE RATES MACK ETAY(B)673A WITH STANDARD R BOSCH SYSTEM (13-MODE FTP WEIGHTING FACTORS), RUN 2

						Weighted			
Engine rpm/% load	Power kW	Fuel kg/hr	Particulate g/hr	$SO_4^=$ mg/hr	Wgt. Fact	Power kW	Fuel kg/hr	Part. g/hr	$SO_4^=$ mg/hr
Idle	--	1.4	8.50	326.0	0.067	--	0.09	0.57	21.84
1450/2	4.3	3.9	15.25	424.4	0.08	0.34	0.31	1.22	33.95
1450/25	54.1	12.8	34.88	2206.1	0.08	4.33	1.02	2.79	176.49
1450/50	108.1	23.7	84.27	3996.1	0.08	8.65	1.90	6.74	319.69
1450/75	162.6	35.6	136.10	6636.2	0.08	13.01	2.85	10.89	530.90
1450/100	216.3	46.9	285.17	10386.5	0.08	17.30	3.75	22.81	830.92
Idle	--	1.4	8.50	326.0	0.067	--	0.09	0.57	21.84
1900/100	239.0	55.4	198.71	15661.0	0.08	19.12	4.43	15.90	1252.88
1900/75	178.8	41.4	104.26	7937.6	0.08	14.30	3.31	8.34	635.01
1900/50	119.0	28.3	81.61	6025.2	0.08	9.25	2.26	6.53	482.02
1900/25	61.4	17.1	49.30	2703.9	0.08	4.91	1.37	3.94	216.31
1900/2	4.3	6.8	29.45	838.3	0.08	0.34	0.54	2.36	67.06
Idle	--	1.4	8.50	326.0	0.067	--	0.09	0.57	21.84
						91.82	22.01	83.23	4610.75

Brake Specific Particulate, g/kW-hr	0.906
Fuel Specific Particulate, g/kg fuel	3.782
Brake Specific $SO_4^=$, mg/kW-hr	50.215
Fuel Specific $SO_4^=$, mg/kg fuel	209.484

TABLE D-96. BRAKE AND FUEL SPECIFIC BaP RATE - 7-MODE CYCLE
MACK ETAY(B)673A ENGINE - STANDARD PUMP

Mode	Engine rpm	Engine load, %	Power kW	Fuel kg/hr	BaP μg/hr	Org. Sol., %	Wgt. Fact.	Power kW	Fuel kg/hr	BaP μg/hr	Org. Sol., %
							W.F. Derived From 13-Mode FTP				
1	1450	2	4.3	3.7	39.87	32.50	0.12	0.52	0.44	4.78	3.90
2	1450	50	108.1	22.9	BMD	4.92	0.16	17.30	3.66	----	0.79
3	1450	100	217.7	46.8	BMD	7.38	0.12	26.12	5.62	----	0.89
4	Idle	---	-----	1.0	32.33	21.30	0.20	-----	0.20	6.47	4.26
5	1900	100	240.9	55.4	BMD	9.15	0.12	28.91	6.65	----	1.10
6	1900	50	118.5	28.4	BMD	4.54	0.16	18.96	4.54	----	0.73
7	1900	2	4.3	6.7	82.28	38.65	0.12	0.52	0.80	9.87	4.64
								92.33	21.91	21.12	16.31

Brake Specific BaP, μg/kW-hr	0.229
Fuel Specific BaP, μg/kg fuel	0.964
Cycle Specific Organic Solubles, %	16.31

W.F. Derived From 21-Mode EPA

Wgt. Fact.	Power kW	Fuel kg/hr	BaP μg/hr	Org. Sol., %
0.225	0.97	0.83	8.97	7.31
0.092	9.95	2.11	----	0.45
0.049	10.67	2.29	----	0.36
0.269	-----	0.27	8.70	5.73
0.176	42.40	9.75	----	1.61
0.110	13.04	3.12	----	0.50
0.079	0.34	0.53	6.50	3.05
	77.37	18.90	24.17	19.01

Brake Specific BaP, μg/kW-hr	0.312
Fuel Specific BaP, μg/kg fuel	1.279
Cycle Specific Organic Solubles, %	19.01

BMD - Below Minimum Detectable

TABLE D-97. BRAKE AND FUEL SPECIFIC BaP RATE - 7-MODE CYCLE
MACK ETAY(B)673A ENGINE - APS PUMP

Mode	Engine rpm	Engine load, %	Power kW	Fuel kg/hr	BaP µg/hr	Org. Sol., %	Wgt. Fact.	Power kW	Fuel kg/hr	BaP µg/hr	Org. Sol., %
							W.F. Derived From 13-Mode FTP				
1	1450	2	7.2	4.6	BMD	36.19	0.12	0.86	0.55	----	4.34
2	1450	50	117.1	24.8	BMD	14.10	0.16	18.74	3.97	----	2.26
3	1450	100	235.0	49.0	BMD	12.57	0.12	28.20	5.88	----	1.51
4	Idle	---	-----	1.0	16.06	23.69	0.20	-----	0.20	3.21	4.74
5	1900	100	243.7	55.1	BMD	0	0.12	29.24	6.61	----	0
6	1900	50	122.8	28.6	BMD	9.72	0.16	19.65	4.58	----	1.56
7	1900	2	5.2	6.8	41.56	21.00	0.12	0.62	0.82	4.99	2.52
								97.31	22.61	8.20	16.93

Brake Specific BaP, µg/kW-hr 0.084
Fuel Specific BaP, µg/kg fuel 0.363
Cycle Specific Organic Solubles, % 16.93

Wgt. Fact.	Power kW	Fuel kg/hr	BaP µg/hr	Org. Sol., %
W.F. Derived From 21-Mode EPA				
0.225	1.62	1.04	----	8.14
0.092	10.77	2.28	----	1.30
0.049	11.52	2.40	----	0.62
0.269	-----	0.27	4.32	6.37
0.176	42.89	9.70	----	0
0.110	13.51	3.15	----	1.07
0.079	0.41	0.54	3.28	1.66
	80.72	19.38	7.60	19.16

Brake Specific BaP, µg/kW-hr 0.094
Fuel Specific BaP, µg/kg fuel 0.392
Cycle Specific Organic Solubles, % 19.16

BMD - Below Minimum Detectable

TABLE D-98. METALS ANALYSIS OF FILTER-COLLECTED PARTICULATE
(PERCENT BY WEIGHT BASED ON FLUOROPORE FILTER SAMPLES)
MACK ETAY(B)673A

Condition Speed/% Load	Configuration	Si	P	S	Cl	Ca	Ti	Fe	Zn
Inter/02	Std pump			1.6		0.15			
	APS pump			1.4		0.07			
Inter/25	Std pump			2.7					
	APS pump			4.8		0.16			
Inter/50	Std pump			2.5		0.02			
	APS pump		0.06	7.1		0.13			
Inter/75	Std pump			1.8		0.02			
	APS pump		0.05	6.7		0.26		0.18	0.14
Inter/100	Std pump			1.6	0.08	0.04			
	APS pump			5.0		0.19			
Idle	Std pump			1.3					
	APS pump	0.12		2.7		0.18			
High/100	Std pump		0.09	4.0		0.20			0.16
	APS pump		0.30	7.3		1.0			0.60
High/75	Std pump		0.05	3.9		0.09	0.02		
	APS pump		0.12	8.8		0.29			0.27
High/50	Std pump			2.6		0.04			
	APS pump		0.09	8.7					0.24
High/25	Std pump			2.6		0.07			
	APS pump			4.9		0.09			
High/02	Std pump			1.8					
	APS pump			1.7					

TABLE D-99. PERCENT PER STAGE OF TOTAL PARTICULATE COLLECTED BY ANDERSON IMPACTOR FOR MACK ETAY(B)673A

Stage	ECD,	1450			650	1900		
No.	micron	2%	50%	100%	Idle	100%	50%	2%
		with A. Bosch APS High Pressure Injection System						
1	10.9	0.20	0.26	0.27	0.30	1.1	0.21	0.29
2	6.8	0.20	0.30	0.60	0.50	1.1	0.10	0.15
3	4.6	0.45	0.72	0.98	0.50	1.8	0.21	0.29
4	3.2	0.37	0.64	0.82	0.25	2.0	0.21	0.18
5	2.0	0.29	0.68	1.5	0.30	2.6	0.47	0.26
6	1.03	0.20	1.6	2.6	0.85	3.3	1.0	0.95
7	0.63	0.20	2.6	4.9	0.80	3.4	2.2	0.55
8	0.42	0.61	3.9	6.8	0.30	4.4	2.0	1.3
Filter	< 0.42	97.5	89.3	81.6	96.2	80.2	93.5	96.0
		with R. Bosch (New) Standard Injection System						
1	10.9	0.38	0.12	0.17	0.23	0.19	0.07	0.81
2	6.8	1.1	0.34	0.38	0.15	0.28	0.14	1.1
3	4.6	1.2	0.46	0.80	0.34	0.79	0.25	1.2
4	3.2	0.70	0.61	0.91	0.42	1.71	0.46	1.2
5	2.0	1.7	1.2	2.0	0.54	2.1	0.95	1.2
6	1.03	1.3	2.2	5.2	0.58	4.8	0.74	2.5
7	0.63	1.6	3.0	8.7	1.2	7.9	1.3	1.5
8	0.42	2.0	4.8	9.8	0.84	8.1	2.7	1.5
Filter	< 0.42	90.0	87.2	72.1	95.7	74.1	93.4	89.0

TABLE D-100. ALDEHYDES BY DNPH FOR MACK ETAY(B)673A WITH A BOSCH APS SYSTEM

Aldehyde	Rate	1450 rpm				1900 rpm		
		2	50	100	Idle	100	50	2
Form-aldehyde	$\mu g/m^3$	4535	883	1143	1338	1069	1031	13780
	mg/hr	2849	871	1718	402	2026	1374	11815
	mg/kg fuel	722	35	35	239	37	49	1649
	mg/kw-hr	606	7	7	-----	9	11	2514
Acet-aldehyde	$\mu g/m^3$	1747	0	0	1072	0	0	5006
	mg/hr	2372	0	0	695	0	0	9277
	mg/kg fuel	601	0	0	414	0	0	1295
	mg/kw-hr	505	0	0	-----	0	0	1974
Acetone	$\mu g/m^3$	4648	0	0	0	0	0	353
	mg/hr	10848	0	0	0	0	0	1124
	mg/kg fuel	2749	0	0	0	0	0	157
	mg/kw-hr	2308	0	0	0	0	0	239
Iso-butanal	$\mu g/m^3$	93	0	0	0	0	0	446
	mg/hr	336	0	0	0	0	0	2199
	mg/kg fuel	85	0	0	0	0	0	307
	mg/kw-hr	72	0	0	0	0	0	468
Crotonal	$\mu g/m^3$	548	79	127	413	0	48	563
	mg/hr	1880	428	1043	677	0	347	2640
	mg/kg fuel	476	17	21	403	0	12	368
	mg/kw-hr	400	4	4	-----	0	3	562
Hexanal	$\mu g/m^3$	292	281	378	11	292	292	297
	mg/hr	2044	3087	6333	37	6167	4332	2841
	mg/kg fuel	518	124	128	22	114	155	397
	mg/kw-hr	435	26	27	-----	26	36	605
Benz-aldehyde	$\mu g/m^3$	746	0	682	1260	851	61	1136
	mg/hr	5839	0	12783	4711	20110	1006	12132
	mg/kg fuel	1480	0	257	2807	371	36	1693
	mg/kw-hr	1242	0	54	-----	85	8	2581

TABLE D-101. ALDEHYDES BY DNPH FOR MACK ETAY(B)673A WITH STANDARD R. BOSCH SYSTEM - NEW

		1450 rpm				1900 rpm		
Aldehyde	Rate	2	50	100	Idle	100	50	2
Form-aldehyde	$\mu g/m^3$	2332	950	781	2462	1626	1784	2732
	mg/hr	1466	937	1173	739	3084	2376	2342
	mg/kg fuel	371	38	24	440	57	85	327
	mg/kw hr	312	8	5	----	13	20	498
Acet-aldehyde	$\mu g/m^3$	586	246	0	1539	164	132	1204
	mg/hr	796	524	0	998	672	381	2232
	mg/kg fuel	202	21	0	595	12	14	311
	mg/kw-hr	170	4	0	----	3	3	475
Acetone	$\mu g/m^3$	0	0	0	489	1025	39	430
	mg/hr	0	0	0	545	7222	191	1371
	mg/kg fuel	0	0	0	325	133	7	191
	mg/kw-hr	0	0	0	----	30	2	292
Iso-butyr-aldehyde	$\mu g/m^3$	89	74	74	334	89	78	244
	mg/hr	322	418	637	576	973	594	1205
	mg/kg fuel	82	17	13	343	18	21	168
	mg/kw-hr	69	4	3	----	4	5	256
Crotonal	$\mu g/m^3$	369	397	460	548	369	361	524
	mg/hr	1267	2139	3781	898	3824	2628	2454
	mg/kg fuel	321	86	76	535	71	94	342
	mg/kw-hr	270	18	16	----	16	22	522
Hexanal	$\mu g/m^3$	95	0	300	131	392	39	114
	mg/hr	662	0	5029	437	8282	578	1089
	mg/kg fuel	168	0	101	260	153	21	152
	mg/kw-hr	141	0	21	----	35	5	232
Benz-aldehyde	$\mu g/m^3$	775	503	235	166	348	108	672
	mg/hr	1692	26921	10661	2414	34492	10933	7178
	mg/kg fuel	429	1085	215	1439	636	391	1002
	mg/kw-hr	360	226	45	----	145	90	1527

TABLE D-102. SPECIFIC HYDROCARBON EMISSION RATES, MACK ETAY(B)673A WITH A. BOSCH APS SYSTEM

Hydrocarbon	Rate	1450 rpm			Idle	1900 rpm		
		2	50	100		100	50	2
Methane CH_4	$\mu g/m^3$	4608	939	493	2770	453	633	4941
	mg/hr	2160	691	553	620	641	629	3161
	mg/kg fuel	547	28	11	370	12	23	441
	mg/kw-hr	460	6	2	----	3	5	673
Ethylene C_2H_4	$\mu g/m^3$	14734	4323	9328	4224	10295	3152	21440
	mg/hr	6906	3182	10459	946	14561	3132	13711
	mg/kg fuel	1750	128	211	563	268	112	1913
	mg/kw-hr	1469	27	44	----	61	26	2917
Ethane C_2H_6	$\mu g/m^3$	262	6	0	125	0	0	331
	mg/hr	123	5	0	28	0	0	212
	mg/kg fuel	31	0	0	17	0	0	30
	mg/kw-hr	26	0	0	----	0	0	45
Acetylene C_2H_2	$\mu g/m^3$	1359	244	1272	314	1039	211	2008
	mg/hr	636	179	1425	70	1468	210	1283
	mg/kg fuel	161	7	29	42	27	8	179
	mg/kw-hr	135	2	6	----	6	2	273
Propane C_3H_8	$\mu g/m^3$	444	17	12	427	17	12	75
	mg/hr	220	1	14	101	26	12	51
	mg/kg fuel	56	1	0	60	1	0	7
	mg/kw-hr	47	0	0	----	0	0	11
Propylene C_3H_6	$\mu g/m^3$	5197	2092	3175	1497	3309	1387	7900
	mg/hr	2436	1539	3560	335	4681	1378	5052
	mg/kg fuel	517	62	72	200	86	49	705
	mg/kw-hr	518	13	15	----	20	11	1075
Benzene C_6H_6	$\mu g/m^3$	1298	629	978	185	1062	404	2758
	mg/hr	585	446	1055	40	1445	387	1698
	mg/kg fuel	148	18	21	24	27	14	237
	mg/kw-hr	125	4	5	----	6	3	361
Toluene C_7H_8	$\mu g/m^3$	2121	756	1008	137	460	427	696
	mg/hr	991	555	1128	31	649	424	444
	mg/kg fuel	251	22	23	18	12	15	62
	mg/kw-hr	211	5	5	----	3	4	94

TABLE D-103. SPECIFIC HYDROCARBON EMISSION RATES, MACK ETAY(B)673A WITH STANDARD R. BOSCH SYSTEM-NEW

		1450 rpm				1900 rpm		
Hydrocarbon	Rate	2	50	100	Idle	100	50	2
Methane	$\mu g/m^3$	3276	959	479	2977	666	872	3090
CH_4	mg/hr	1536	706	538	667	942	867	1976
	mg/kg fuel	389	29	11	379	17	31	276
	mg/kw-hr	327	6	2	----	4	7	421
Ethylene	$\mu g/m^3$	7551	6695	5762	7149	7283	5716	8331
C_2H_4	mg/hr	3539	4927	6461	1600	10301	5678	5328
	mg/kg fuel	897	199	130	954	190	203	743
	mg/kw-hr	753	41	27	----	43	47	1134
Ethane	$\mu g/m^3$	144	50	0	144	12	19	144
C_2H_6	mg/hr	67	37	0	32	18	19	91
	mg/kg fuel	17	2	0	19	0	1	13
	mg/kw-hr	14	0	0	----	0	0	20
Acetylene	$\mu g/m^3$	785	254	698	574	996	211	866
C_2H_2	mg/hr	367	187	782	128	1407	210	553
	mg/kg fuel	93	8	16	76	26	8	77
	mg/kw-hr	78	2	3	----	6	2	118
Propane	$\mu g/m^3$	0	0	0	0	231	0	0
C_3H_8	mg/hr	0	0	0	0	345	0	0
	mg/kg fuel	0	0	0	0	6	0	0
	mg/kw-hr	0	0	0	0	2	0	0
Propylene	$\mu g/m^3$	2558	3560	1987	2738	2231	3146	3169
C_3H_6	mg/hr	1199	2620	2228	613	3156	3126	2027
	mg/kg fuel	304	106	45	365	58	112	283
	mg/kw-hr	255	22	9	----	13	26	431
Benzene	$\mu g/m^3$	1180	534	747	635	837	478	640
C_6H_6	mg/hr	532	378	806	137	1140	457	394
	mg/kg fuel	135	15	16	82	21	16	55
	mg/kw-hr	113	3	3	----	5	4	84
Toluene	$\mu g/m^3$	1896	833	641	2636	641	553	258
C_7H_8	mg/hr	886	611	717	589	904	548	164
	mg/kg fuel	225	25	14	351	17	20	23
	mg/kw-hr	189	5	3	----	4	5	35

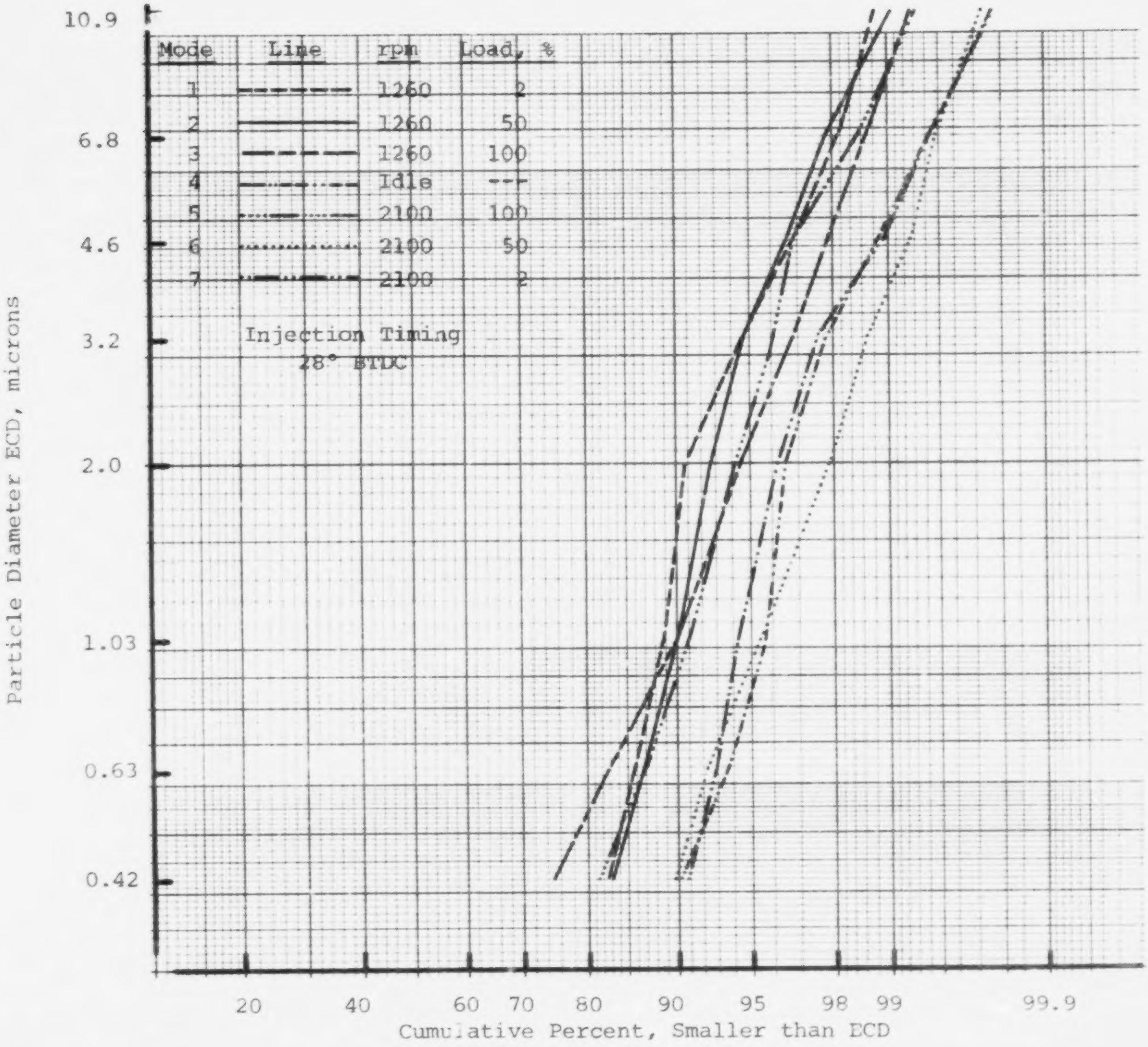

Figure D-1. Particle Size Distribution for Caterpillar 3406, via Impactor Direct Injection, 28° BTC Standard Timing

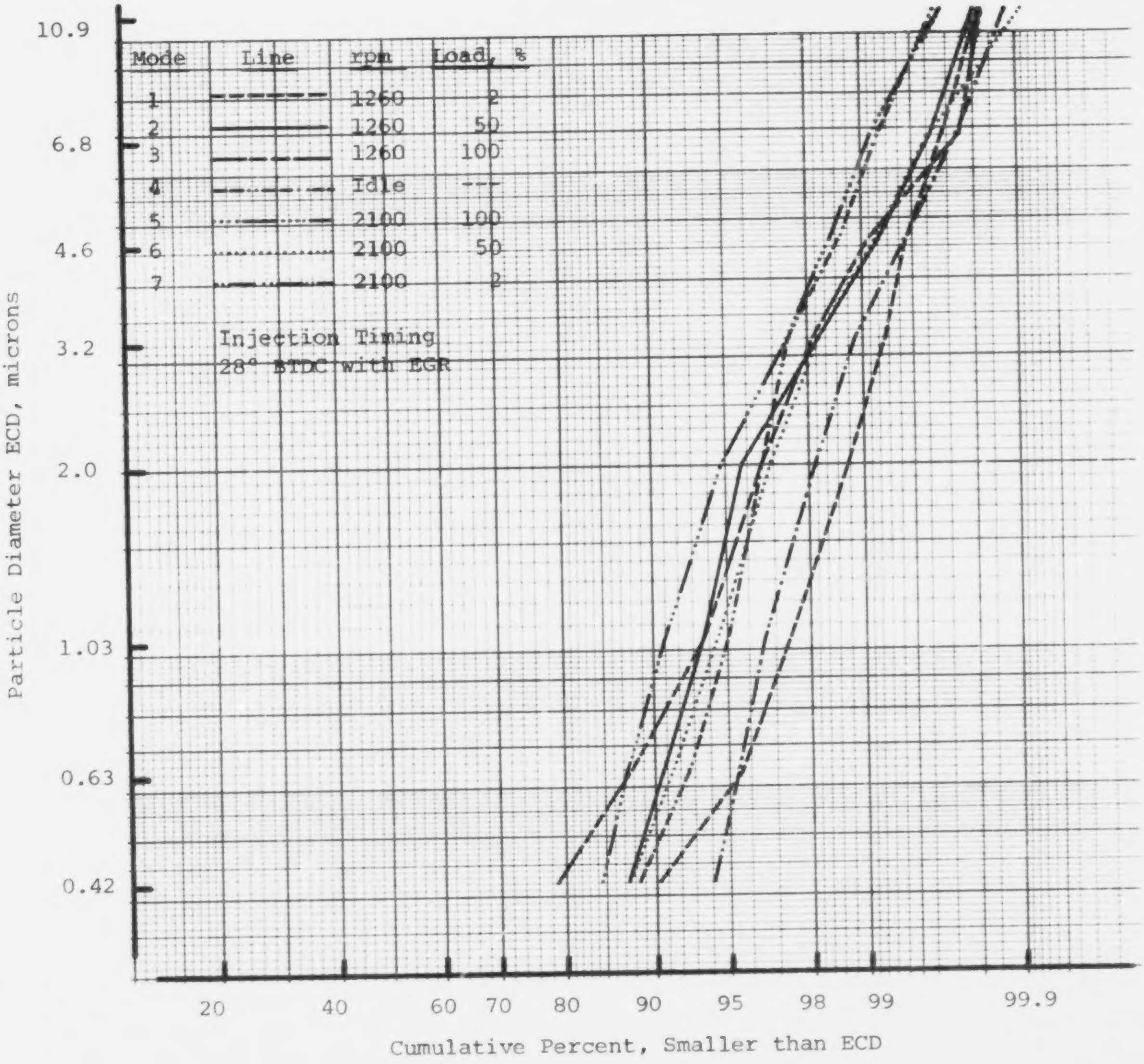

Figure D-2. Particle Size Distribution for Caterpillar 3406, via Impactor Direct Injection, 28° BTC with EGR

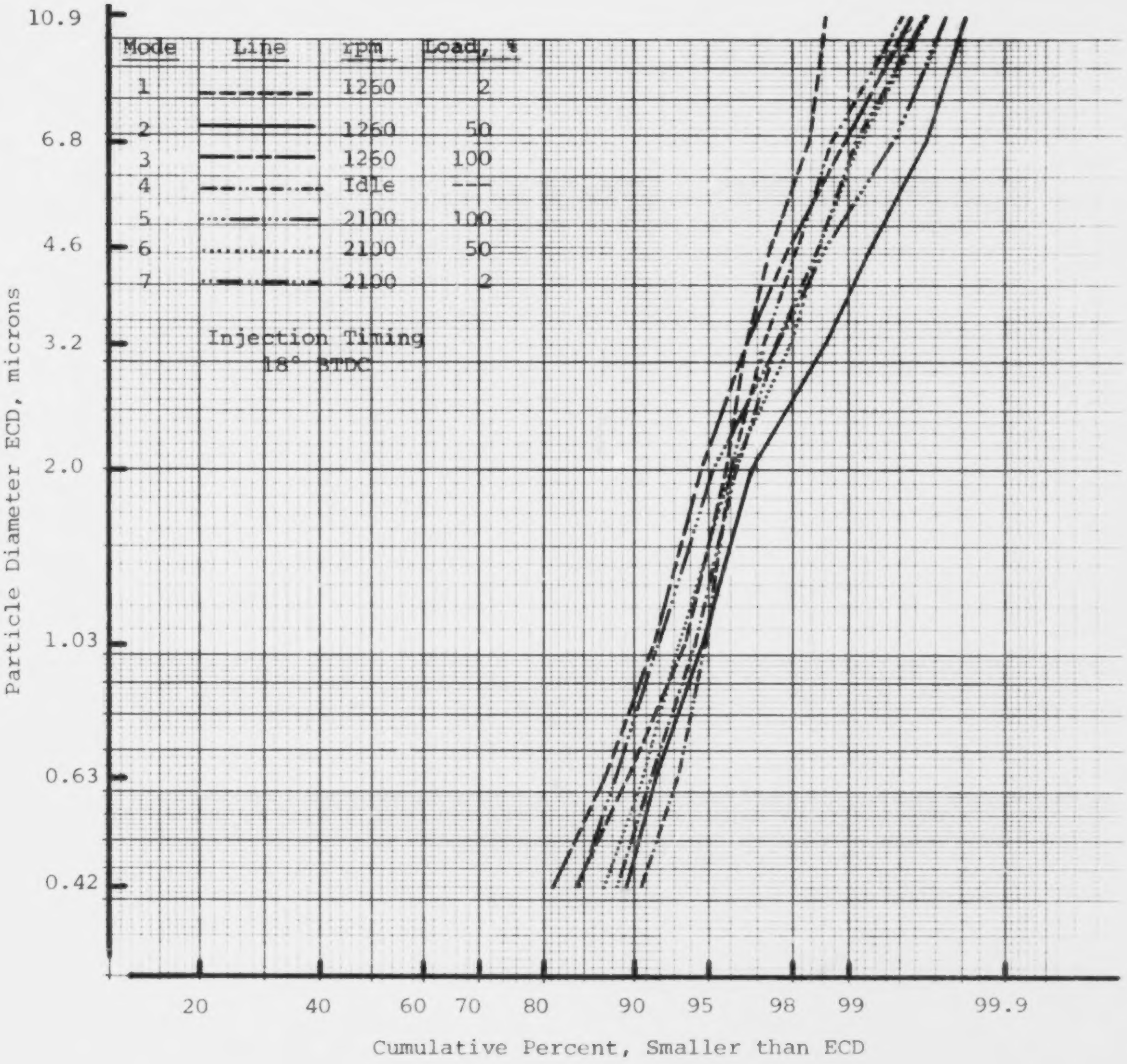

Figure D-3. Particle Size Distribution for Caterpillar 3406, via Impactor Direct Injection, 18° BTC (10° Retard)

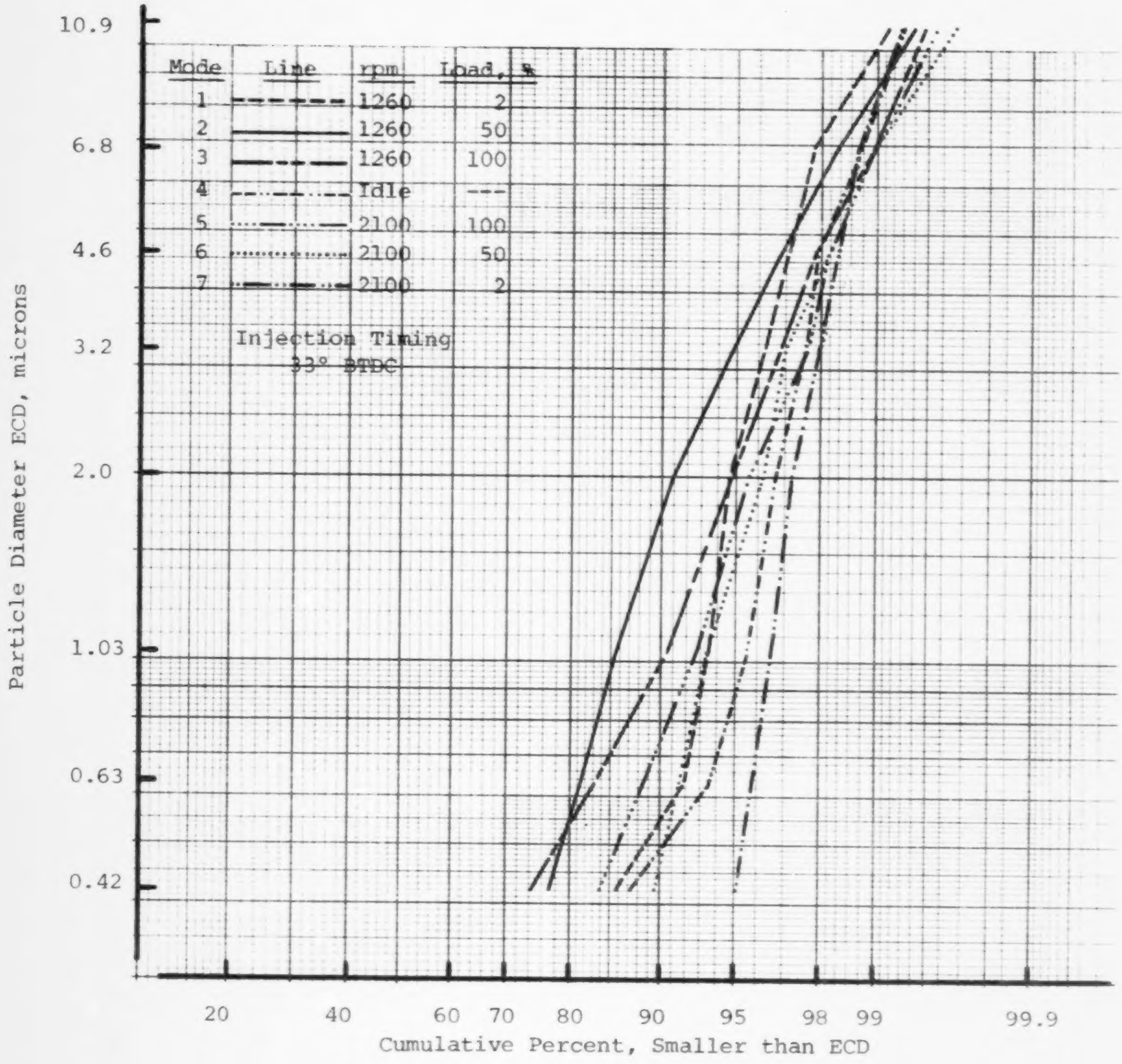

Figure D-4. Particle Size Distribution for Caterpillar 3406, via Impactor Direct Injection, 33° BTC (5° Advance)

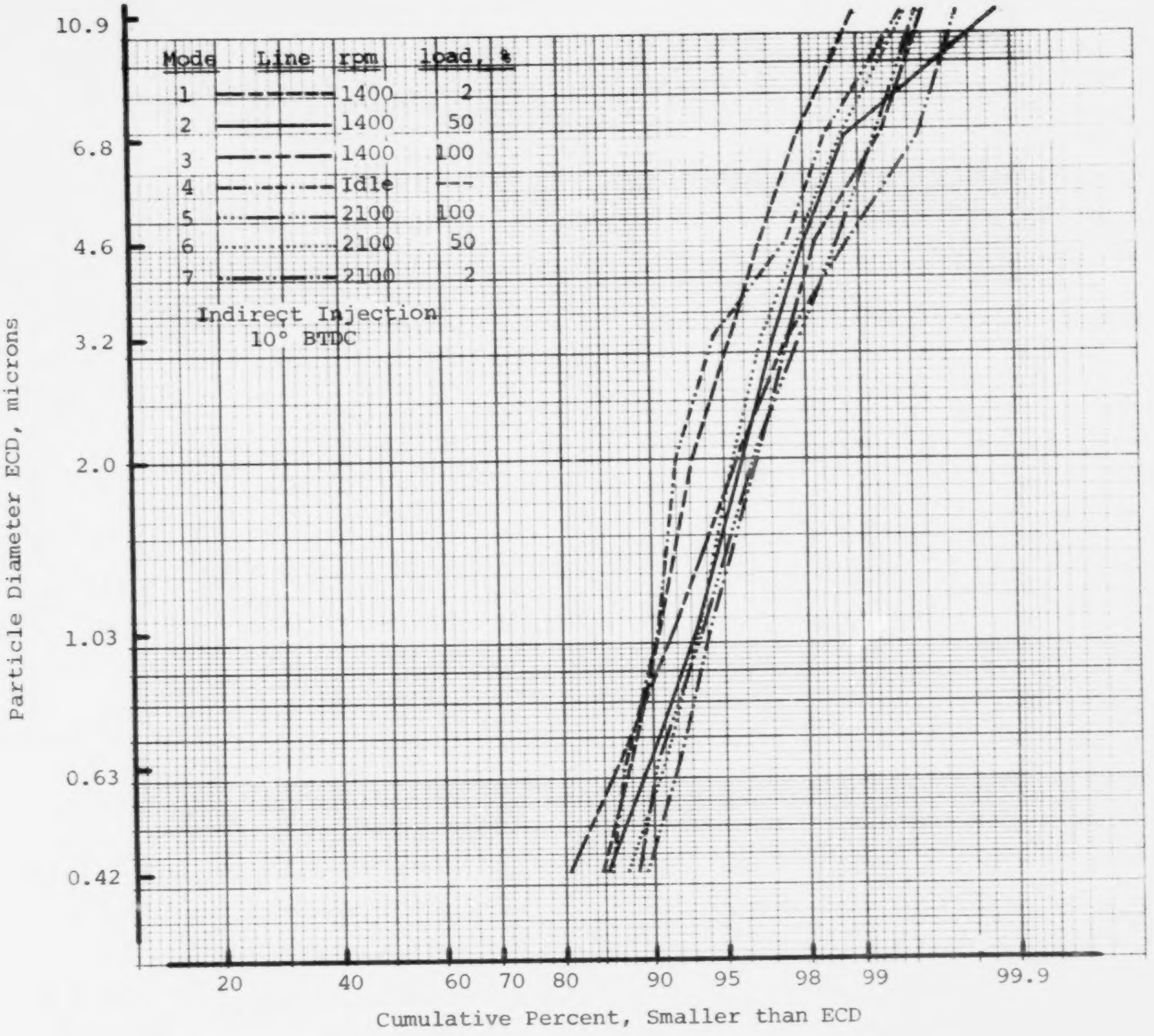

Figure D-5. Particle Size Distribution for Caterpillar 3406, via Impactor Indirect Injection, 10° BTC

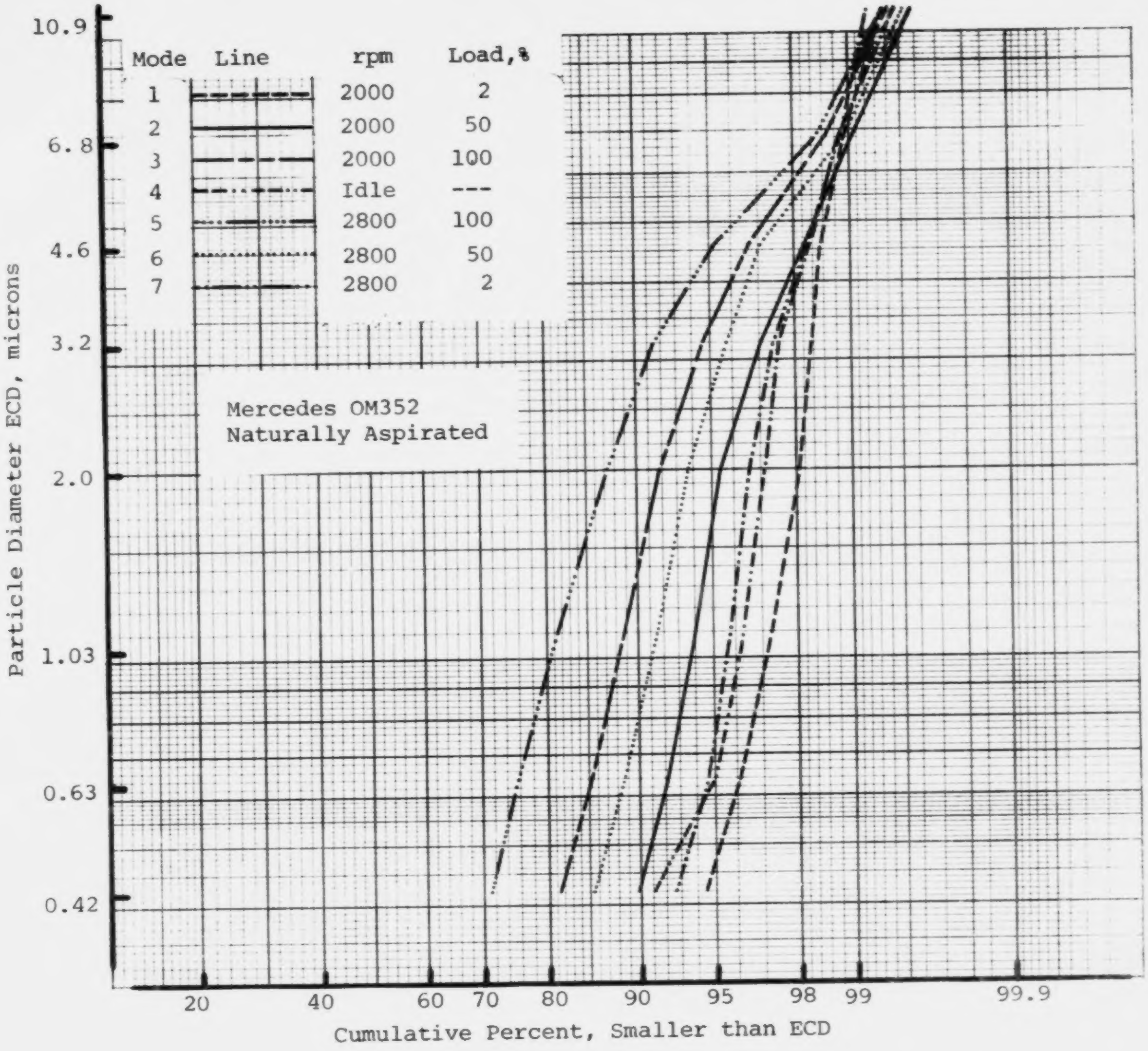

Figure D-6. Particle Size Distribution
for Daimler-Benz OM-352 NA, via Impactor

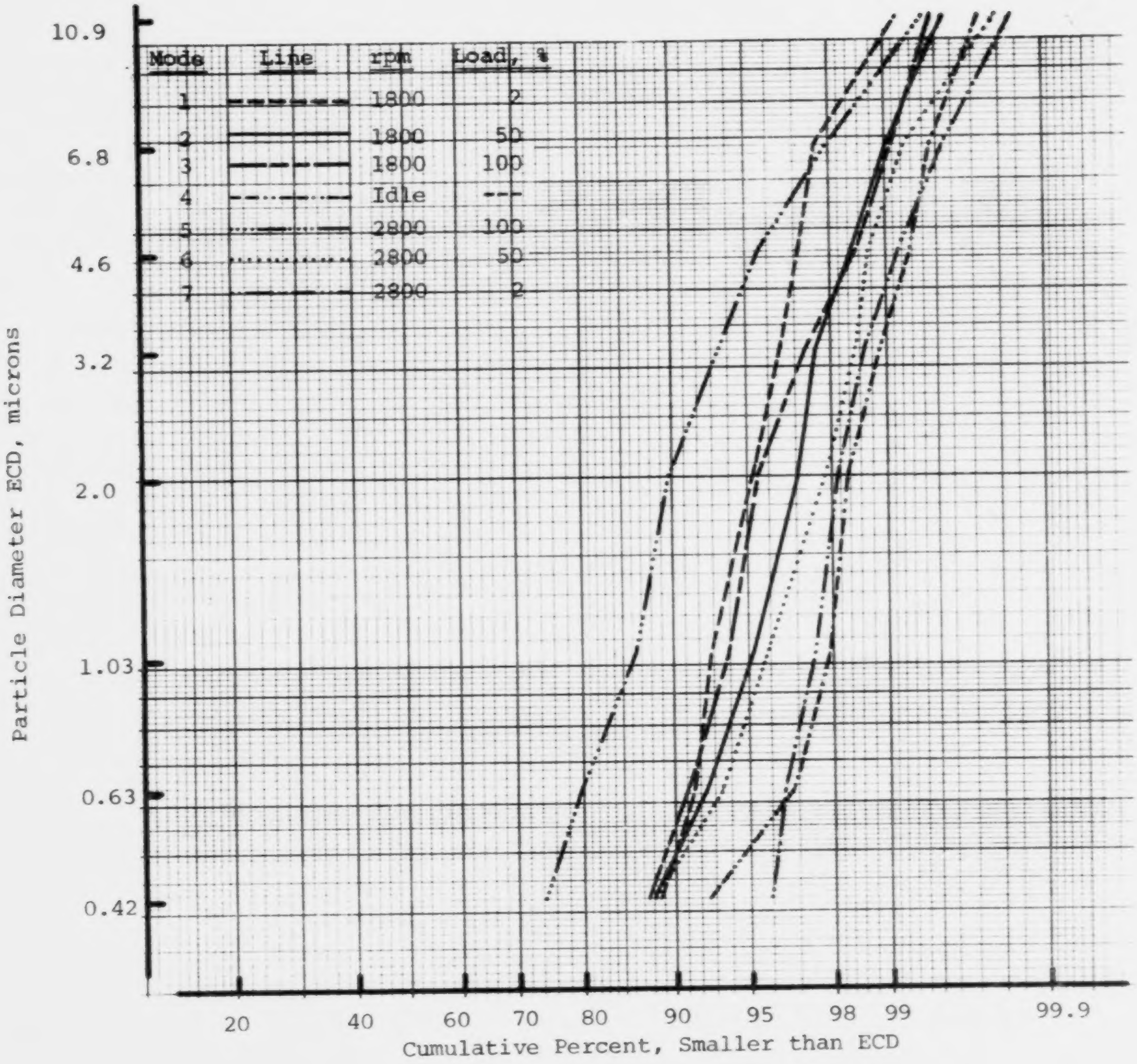

Figure D-7. Particle Size Distribution for
Daimler-Benz OM-352A TC, via Impactor

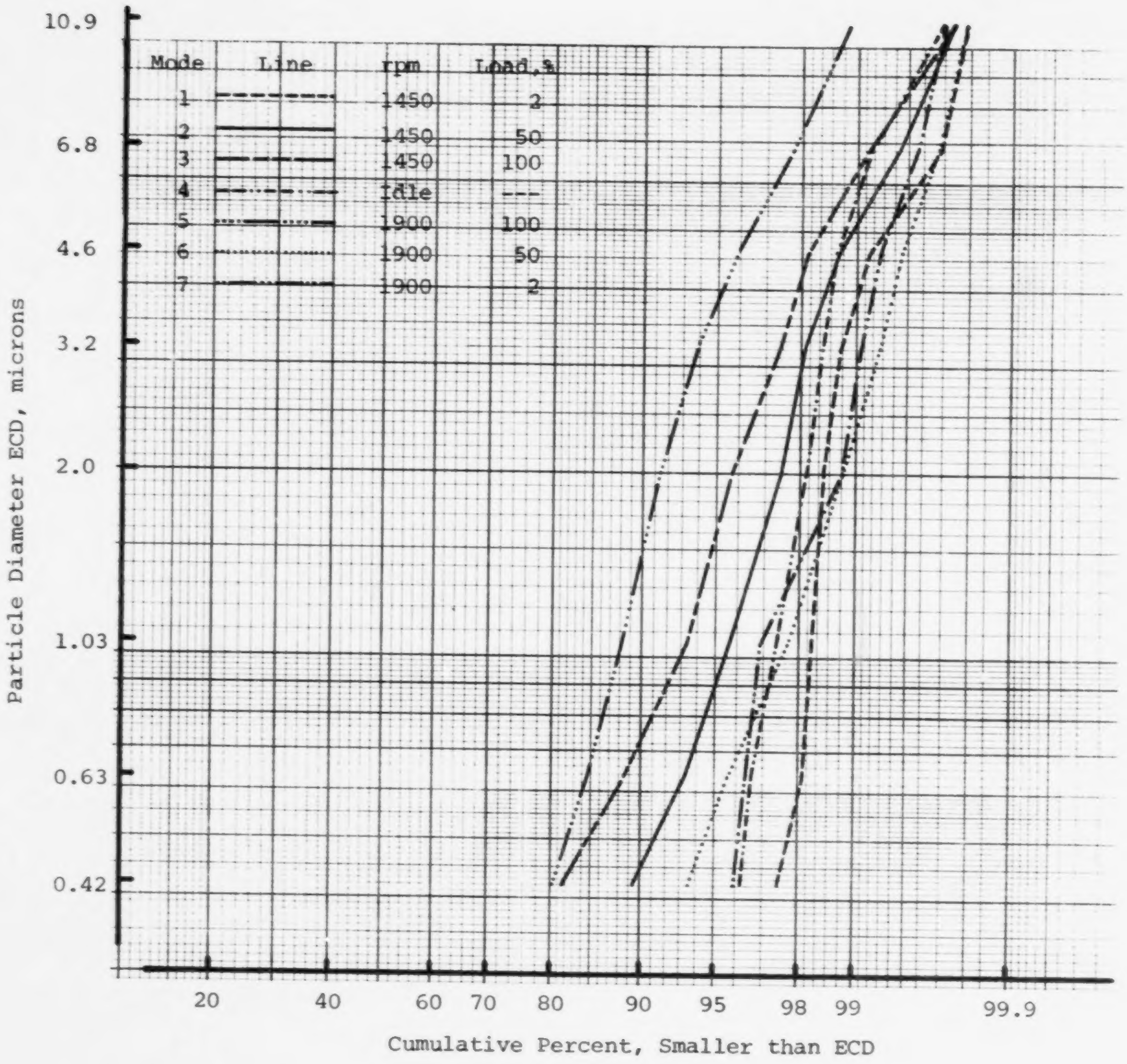

Figure D-8. Particle Size Distribution for Mack ETAY(B)673A + APS, Pump via Impactor

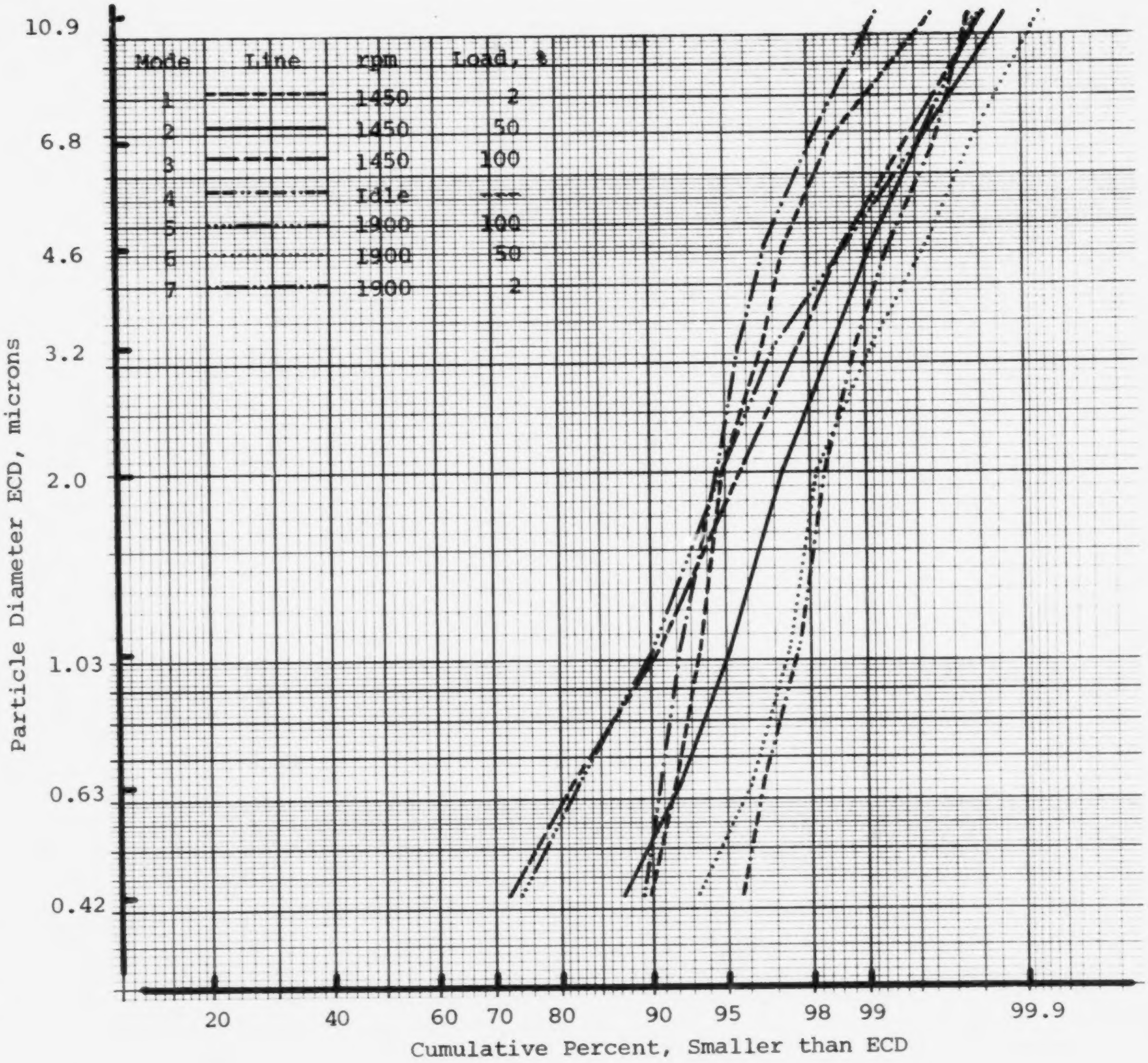

Figure D-9. Particle Size Distribution for Mack ETAY(B)673A + Standard Pump via Impactor

APPENDIX E

COMPUTER REDUCED 1975 FTP, SET AND FET GASEOUS AND FUEL ECONOMY DATA FOR FOUR LD VEHICLES

TABLE E-1. GASEOUS EMISSIONS SUMMARY-1976 OLDS CUTLASS DIESEL
(Transient Cycles)

Cycle	Date	Test No.	Run	Emission Rate, g/km HC	CO	NO_x	Fuel Cons 1/100 km	Fuel Econ mpg
'75 FTP	10/19/76	1	1	0.49	1.29	0.70	11.02	21.35
	10/20/76	2	1	0.47	1.23	0.67	10.88	21.63
	10/21/76	3	1	0.45	1.21	0.73	10.63	22.14
	Average			0.47	1.24	0.70	10.84	21.71
				(0.756)	(1.995)	(1.126)		
FTP_c	10/19/76	1	1	0.61	1.42	0.70	11.68	20.15
	10/20/76	2	1	0.59	1.35	0.68	11.55	20.37
	10/21/76	3	1	0.56	1.33	0.73	11.14	21.12
	Average			0.59	1.37	0.70	11.46	20.53
				(0.949)	(2.204)	(1.126)		
FTP_h	10/19/76	1	1	0.40	1.21	0.70	10.44	22.54
			2	0.37	1.14	0.65	10.24	22.97
			3	0.36	1.15	0.72	10.38	22.67
			4	0.37	1.16	0.67	10.39	22.65
			5	0.36	1.13	0.70	10.23	23.00
	10/20/76	2	1	0.37	1.13	0.69	10.33	22.78
	10/21/76	3	1	0.37	1.14	0.73	10.30	22.84
			2	0.35	1.06	0.75	9.80	24.01
			3	0.33	1.09	0.68	10.06	23.39
			4	0.35	1.03	0.64	9.38	25.09
			5	0.35	1.07	0.65	9.87	23.85
	Average			0.36	1.12	0.69	10.13	23.25
				(0.579)	(1.802)	(1.110)		
Standard Deviation				0.02	0.05	0.04	0.33	0.78
Coefficient of Variation,%				4.9	4.6	5.1	3.3	3.3
SET	10/19/76	1	1	0.29	0.83	0.63	8.85	26.59
	10/20/76	2	1	0.26	0.77	0.60	8.45	27.85
	10/21/76	3	1	0.25	0.78	0.55	8.91	26.41
	Average			0.27	0.79	0.59	8.74	26.92
				(0.434)	(1.271)	(0.949)		
FET	10/19/76	1	1	0.23	0.64	0.61	7.76	30.32
	10/20/76	2	1	0.22	0.62	0.55	7.34	32.06
	10/21/76	3	1	0.18	0.64	0.62	7.43	31.67
	Average			0.21	0.63	0.59	7.51	31.33
				(0.337)	(1.014)	(0.949)		

( )Values in parentheses are in grams/mile

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                              TABLE E-2            VEHICLE EMISSION RESULTS
                                        1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.  111       TEST NO. 1          DATE 10/19/76                  MFGR. CODE   -0              YR. 1976
VEHICLE MODEL  OLDS DIESEL CTLS         ENGINE   5.74 LITRE 8 CYL.     TEST WT.  2041 KG            ROAD LOAD    9.5 KW
TEST TYPE  3J29R6M181269                COMMENTS

BAROMETER 744.47 MM OF HG.                                             WET BULB TEMP  16.7 DEG. C
DRY BULB TEMP.   24.4 DEG. C                                            ABS. HUMIDITY   8.7 MILLIGRAMS/KG
REL. HUMIDITY     45 PCT.
EXHAUST EMISSIONS
                                                                       BLOWER INLET PRESS., G1 266.7 MM. H2O
    BLOWER DIF. PRESS., G2, 304.8 MM. H2O                              BLOWER INLET TEMP.   43 DEG. C

    BAG RESULTS
    BAG NO.                                         1           2           3
    BLOWER REVOLUTIONS                           7510       12901        7525
    HC   SAMPLE  METER READING/SCALE           17.8/4       7.0/4      16.7/3
    HC   SAMPLE  PPM                              142          56          67
    HC   BACKGRD METER READING/SCALE             .3/4        .7/4       1.2/3
    HC   BACKGRD PPM                                2           6           5
    CO   SAMPLE  METER READING/SCALE           63.3/*      37.7/*      45.9/*
    CO   SAMPLE  PPM                              141          78          98
    CO   BACKGRD METER READING/SCALE             .3/*        .1/*        .5/*
    CO   BACKGRD PPM                                1           0           1
    CO2  SAMPLE  METER READING/SCALE           44.1/2      27.5/2      36.3/2
    CO2  SAMPLE  PERCENT                         1.96        1.13        1.55
    CO2  BACKGRD METER READING/SCALE            2.8/2       2.6/2       1.5/2
    CO2  BACKGRD PERCENT                          .10         .09         .05
    NOX  SAMPLE  METER READING/SCALE           39.8/2      26.5/2      40.6/2
    NOX  SAMPLE  PPM                             39.8        26.5        40.6
    NOX  BACKGRD METER READING/SCALE             .9/2        .6/2        .8/2
    NOX  BACKGRD PPM                               .9          .6          .8

    HC   CONCENTRATION PPM                        140          51          62
    CO   CONCENTRATION PPM                        133          75          93
    CO2  CONCENTRATION PCT                       1.87        1.04        1.50
    NOX  CONCENTRATION PPM                       39.0        26.0        39.9
    HC   MASS GRAMS                              4.52        2.81        2.02
    CO   MASS GRAMS                              8.69        8.44        6.05
    CO2  MASS GRAMS                           1925.62     1838.39     1550.92
    NOX  MASS GRAMS                              3.93        4.48        4.02
     HC   MASS MG                                4.52        2.81        2.02

    WEIGHTED MASS HC       .49 GRAMS/KILOMETRE
    WEIGHTED MASS CO      1.29 GRAMS/KILOMETRE
    WEIGHTED MASS CO2   294.21 GRAMS/KILOMETRE
    WEIGHTED MASS NOX      .70 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION = 11.02 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =   208.4 STD. CU. METRES
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                    TABLE E-3                  VEHICLE EMISSION RESULTS
                         1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.              TEST NO. 1      DATE 10/19/76                  MFGR. CODE   -0                YR. 1976
VEHICLE MODEL  OLDS DIESEL CTLS       ENGINE   5.74 LITRE 8 CYL.     TEST WT.  2041 KG              ROAD LOAD    9.5 KW
TEST TYPE  3J29R6M1R1269              COMMENTS  1975 FTP 2 BAG COLD

BAROMETER 744.47 MM OF HG.                                      WET BULB TEMP  16.7 DEG. C
DRY BULB TEMP.    24.4 DEG. C                                    ABS. HUMIDITY   8.7 MILLIGRAMS/KG
REL. HUMIDITY      45 PCT.
EXHAUST EMISSIONS
                                                                BLOWER INLET PRESS., G1 266.7 MM. H2O
    BLOWER DIF. PRESS., G2, 304.8 MM. H2O                       BLOWER INLET TEMP.   43 DEG. C

    BAG RESULTS
    BAG NO.                                     1              2              3
    BLOWER REVOLUTIONS                       7510          12901           7510
    HC    SAMPLE  METER READING/SCALE        17.8/4          7.0/4         17.8/4
    HC    SAMPLE  PPM                        142             56            142
    HC    BACKGRD METER READING/SCALE         .3/4           .7/4           .3/4
    HC    BACKGRD PPM                         2              6              2
    CO    SAMPLE  METER READING/SCALE        63.3/*         37.7/*         63.3/*
    CO    SAMPLE  PPM                        141             78            141
    CO    BACKGRD METER READING/SCALE         .3/*           .1/*           .3/*
    CO    BACKGRD PPM                         1              0              1
    CO2   SAMPLE  METER READING/SCALE        44.1/2         27.5/2         44.1/2
    CO2   SAMPLE  PERCENT                    1.96           1.13           1.96
    CO2   BACKGRD METER READING/SCALE         2.8/2          2.6/2          2.8/2
    CO2   BACKGRD PERCENT                     .10            .09            .10
    NOX   SAMPLE  METER READING/SCALE        39.8/2         26.5/2         39.8/2
    NOX   SAMPLE  PPM                        39.8           26.5           39.8
    NOX   BACKGRD METER READING/SCALE          .9/2           .6/2           .9/2
    NOX   BACKGRD PPM                         .9             .6             .9

    HC    CONCENTRATION PPM                  140             51            140
    CO    CONCENTRATION PPM                  133             75            133
    CO2   CONCENTRATION PCT                  1.87           1.04           1.87
    NOX   CONCENTRATION PPM                  39.0           26.0           39.0
    HC    MASS GRAMS                         4.52           2.81           4.52
    CO    MASS GRAMS                         8.69           8.44           8.69
    CO2   MASS GRAMS                      1925.62        1838.39        1925.62
    NOX   MASS GRAMS                         3.93           4.48           3.93
     HC    MASS MG                           4.52           2.81           4.52

    WEIGHTED MASS HC        .61 GRAMS/KILOMETRE
    WEIGHTED MASS CO       1.42 GRAMS/KILOMETRE
    WEIGHTED MASS CO2    311.91 GRAMS/KILOMETRE
    WEIGHTED MASS NOX       .70 GRAMS/KILOMETRE

CARBON BALANCE FUEL CONSUMPTION = 11.68 LITRES PER HUNDRED KILOMETRES
TOTAL CVS FLOW =   208.3 STD. CU. METRES
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                         TABLE E-4                   VEHICLE EMISSION RESULTS
                                     1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.            TEST NO. 1  Run 1    DATE 10/19/76                       MFGR. CODE   -0               YR. 1976
VEHICLE MODEL  OLDS DIESEL CTLS          ENGINE    5.74 LITRE 8 CYL.         TEST WT.   2041 KG            ROAD LOAD    9.5 KW
TEST TYPE  3J29R6M1R1269                 COMMENTS  1975 FTP 2 BAG HOT
                                                                             WET BULB TEMP  15.6 DEG. C
BAROMETER 744.73 MM OF HG.                                                    ABS. HUMIDITY   7.7 MILLIGRAMS/KG
DRY BULB TEMP.    23.9 DEG. C
REL. HUMIDITY      41 PCT.
EXHAUST EMISSIONS
                                                                             BLOWER INLET PRESS., G1 266.7 MM. H2O
   BLOWER DIF. PRESS., G2, 304.6 MM. H2O                                     BLOWER INLET TEMP.    43 DEG. C

   BAG RESULTS
   BAG NO.                                      1              2              3
   BLOWER REVOLUTIONS                         7525          12914           7525
   HC   SAMPLE  METER READING/SCALE          16.7/3          14.1/3         16.7/3
   HC   SAMPLE  PPM                            67              56             67
   HC   BACKGRD METER READING/SCALE           1.2/3           1.7/3          1.2/3
   HC   BACKGRD PPM                             5               7              5
   CO   SAMPLE  METER READING/SCALE          45.9/*          38.1/*         45.9/*
   CO   SAMPLE  PPM                            98              79             98
   CO   BACKGRD METER READING/SCALE            .5/*            .6/*           .5/*
   CO   BACKGRD PPM                             1               1              1
   CO2  SAMPLE  METER READING/SCALE          36.3/2          26.6/2         36.3/2
   CO2  SAMPLE  PERCENT                      1.55            1.08           1.55
   CO2  BACKGRD METER READING/SCALE           1.5/2           1.8/2          1.5/2
   CO2  BACKGRD PERCENT                       .05             .07            .05
   NOX  SAMPLE  METER READING/SCALE          40.6/2          27.4/2         40.6/2
   NOX  SAMPLE  PPM                          40.6            27.4           40.6
   NOX  BACKGRD METER READING/SCALE            .8/2            .6/2           .8/2
   NOX  BACKGRD PPM                            .8              .6             .8

   HC   CONCENTRATION PPM                      62              50             62
   CO   CONCENTRATION PPM                      93              76             93
   CO2  CONCENTRATION PCT                    1.50            1.02           1.50
   NOX  CONCENTRATION PPM                    39.9            26.8           39.9
   HC   MASS GRAMS                           2.02            2.79           2.02
   CO   MASS GRAMS                           6.06            8.48           6.06
   CO2  MASS GRAMS                        1551.49         1814.24        1551.49
   NOX  MASS GRAMS                           3.89            4.50           3.89
   HC    MASS MG                             2.02            2.79           2.02

   WEIGHTED MASS HC        .40 GRAMS/KILOMETRE
   WEIGHTED MASS CO       1.21 GRAMS/KILOMETRE
   WEIGHTED MASS CO2    278.91 GRAMS/KILOMETRE
   WEIGHTED MASS NOX       .70 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION = 10.44 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =   208.7 STD. CU. METRES
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                          TABLE  E-5                VEHICLE EMISSION RESULTS
                                 1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.                  TEST NO. 1   Run 2    DATE 10/19/76                  MFGR. CODE   -0                   YR. 1976
VEHICLE MODEL  OLDS DIESEL CTLS                 ENGINE    5.74 LITRE 8 CYL.    TEST WT.  2041 KG             ROAD LOAD    9.5 KW
TEST TYPE  3J29R6M181269                        COMMENTS 1975 FTP Run 2   2 Bag Hot

BAROMETER 744.73 MM OF HG.                                                      WET BULB TEMP  13.9 DEG. C
DRY BULB TEMP.    22.2 DEG. C                                                    ABS. HUMIDITY    6.5 MILLIGRAMS/KG
REL. HUMIDITY      38 PCT.
EXHAUST EMISSIONS

                                                                               BLOWER INLET PRESS., G1 266.7 MM. H2O
     BLOWER DIF. PRESS., G2, 304.8 MM. H2O                                     BLOWER INLET TEMP.    43 DEG. C

     BAG RESULTS
     BAG NO.                                      1             2             3
     BLOWER REVOLUTIONS                        7505         12890          7505
     HC   SAMPLE  METER READING/SCALE        15.6/3        13.0/3        15.6/3
     HC   SAMPLE  PPM                            62            52            62
     HC   BACKGRD METER READING/SCALE         1.5/3         1.1/3         1.5/3
     HC   BACKGRD PPM                             6             4             6
     CO   SAMPLE  METER READING/SCALE        43.8/*        36.2/*        43.8/*
     CO   SAMPLE  PPM                            93            75            93
     CO   BACKGRD METER READING/SCALE          .5/*          .4/*          .5/*
     CO   BACKGRD PPM                             1             1             1
     CO2  SAMPLE  METER READING/SCALE        36.3/2        26.3/2        36.3/2
     CO2  SAMPLE  PERCENT                      1.55          1.07          1.55
     CO2  BACKGRD METER READING/SCALE         2.1/2         2.0/2         2.1/2
     CO2  BACKGRD PERCENT                       .08           .07           .08
     NOX  SAMPLE  METER READING/SCALE        39.2/2        26.6/2        39.2/2
     NOX  SAMPLE  PPM                          39.2          26.6          39.2
     NOX  BACKGRD METER READING/SCALE          .7/2          .6/2          .7/2
     NOX  BACKGRD PPM                            .7            .6            .7

     HC   CONCENTRATION PPM                      57            48            57
     CO   CONCENTRATION PPM                      88            72            88
     CO2  CONCENTRATION PCT                    1.48          1.00          1.48
     NOX  CONCENTRATION PPM                    38.6          26.0          38.6
     HC   MASS GRAMS                           1.85          2.67          1.85
     CO   MASS GRAMS                           5.74          8.03          5.74
     CO2  MASS GRAMS                        1527.15       1774.42       1527.15
     NOX  MASS GRAMS                           3.63          4.21          3.63
      HC   MASS MG                             1.85          2.67          1.85

     WEIGHTED MASS HC        .37 GRAMS/KILOMETRE
     WEIGHTED MASS CO       1.14 GRAMS/KILOMETRE
     WEIGHTED MASS CO2    273.59 GRAMS/KILOMETRE
     WEIGHTED MASS NOX       .65 GRAMS/KILOMETRE

   CARBON BALANCE FUEL CONSUMPTION = 10.24 LITRES PER HUNDRED KILOMETRES
   TOTAL CVS FLOW =    208.2 STD. CU. METRES
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          TABLE  E-6               VEHICLE EMISSION RESULTS
                    1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.              TEST NO. 1   Run 3  DATE 10/19/76                  MFGR. CODE   -0          YR. 1976
VEHICLE MODEL  OLDS DIESEL CTLS           ENGINE    5.74 LITRE 8 CYL.    TEST WT.  2041 KG        ROAD LOAD    9.5 KW
TEST TYPE  3J29R6M181269                  COMMENTS 1975 FTP  2 Bag Hot

                                                                     WET BULB TEMP  16.7 DEG. C
BAROMETER 745.74 MM OF HG.                                            ABS. HUMIDITY   8.7 MILLIGRAMS/KG
DRY BULB TEMP.    24.4 DEG. C
REL. HUMIDITY      45 PCT.
EXHAUST EMISSIONS
                                                                     BLOWER INLET PRESS., G1 254.0 MM. H2O
      BLOWER DIF. PRESS., G2, 304.8 MM. H2O                          BLOWER INLET TEMP.    43 DEG. C

      BAG RESULTS
      BAG NO.                                1           2           3
      BLOWER REVOLUTIONS                  7508       12916        7508
      HC   SAMPLE  METER READING/SCALE    15.1/3      12.7/3      15.1/3
      HC   SAMPLE  PPM                     60          51          60
      HC   BACKGRD METER READING/SCALE     1.9/3       1.3/3       1.9/3
      HC   BACKGRD PPM                     8           5           8
      CO   SAMPLE  METER READING/SCALE    44.5/*      36.3/*      44.5/*
      CO   SAMPLE  PPM                     94          75          94
      CO   BACKGRD METER READING/SCALE      .5/*        .6/*        .5/*
      CO   BACKGRD PPM                     1           1           1
      CO2  SAMPLE  METER READING/SCALE    36.7/2      26.1/2      36.7/2
      CO2  SAMPLE  PERCENT                1.57        1.06        1.57
      CO2  BACKGRD METER READING/SCALE     1.9/2       1.7/2       1.9/2
      CO2  BACKGRD PERCENT                 .07         .06         .07
      NOX  SAMPLE  METER READING/SCALE    40.6/2      27.5/2      40.6/2
      NOX  SAMPLE  PPM                    40.6        27.5        40.6
      NOX  BACKGRD METER READING/SCALE      .8/2        .7/2        .8/2
      NOX  BACKGRD PPM                      .8          .7          .8

      HC   CONCENTRATION PPM               54          46          54
      CO   CONCENTRATION PPM               89          71          89
      CO2  CONCENTRATION PCT              1.51        1.00        1.51
      NOX  CONCENTRATION PPM              39.9        26.9        39.9
      HC   MASS GRAMS                     1.74        2.56        1.74
      CO   MASS GRAMS                     5.84        8.04        5.84
      CO2  MASS GRAMS                  1559.67     1784.60     1559.67
      NOX  MASS GRAMS                     4.02        4.66        4.02
       HC   MASS MG                       1.74        2.56        1.74

       WEIGHTED MASS HC        .36 GRAMS/KILOMETRE
       WEIGHTED MASS CO       1.15 GRAMS/KILOMETRE
       WEIGHTED MASS CO2    277.13 GRAMS/KILOMETRE
       WEIGHTED MASS NOX       .72 GRAMS/KILOMETRE

      CARBON BALANCE FUEL CONSUMPTION = 10.38 LITRES PER HUNDRED KILOMETRES
      TOTAL CVS FLOW =    209.0 STD. CU. METRES
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                         TABLE  E-7                VEHICLE EMISSION RESULTS
                              1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.                TEST NO. 1   Run 4   DATE 10/19/76                   MFGR. CODE   -0                YR. 1976
VEHICLE MODEL  OLDS DIESEL CTLS              ENGINE    5.74 LITRE 8 CYL.     TEST WT.  2041 KG              ROAD LOAD    9.5 KW
TEST TYPE  3J29R6M181269                     COMMENTS 1975 FTP   2 Bag Hot

BAROMETER 745.74 MM OF HG.                                                   WET BULB TEMP  15.0 DEG. C
DRY BULB TEMP.    23.9 DEG. C                                                 ABS. HUMIDITY    7.0 MILLIGRAMS/KG
REL. HUMIDITY      37 PCT.
EXHAUST EMISSIONS

                                                                             BLOWER INLET PRESS., G1 266.7 MM. H2O
   BLOWER DIF. PRESS., G2, 304.8 MM. H2O                                     BLOWER INLET TEMP.    43 DEG. C

   BAG RESULTS
   BAG NO.                                       1             2              3
   BLOWER REVOLUTIONS                          7515         12895           7515
   HC    SAMPLE  METER READING/SCALE           14.9/3        13.3/3         14.9/3
   HC    SAMPLE  PPM                             60            53             60
   HC    BACKGRD METER READING/SCALE            1.7/3         1.3/3          1.7/3
   HC    BACKGRD PPM                              7             5              7
   CO    SAMPLE  METER READING/SCALE           44.5/*        36.9/*         44.5/*
   CO    SAMPLE  PPM                             94            76             94
   CO    BACKGRD METER READING/SCALE             .4/*          .6/*           .4/*
   CO    BACKGRD PPM                              1             1              1
   CO2   SAMPLE  METER READING/SCALE           36.3/2        27.0/2         36.3/2
   CO2   SAMPLE  PERCENT                       1.55          1.10           1.55
   CO2   BACKGRD METER READING/SCALE            2.1/2         2.3/2          2.1/2
   CO2   BACKGRD PERCENT                        .08           .08            .08
   NOX   SAMPLE  METER READING/SCALE           38.6/2        27.4/2         38.6/2
   NOX   SAMPLE  PPM                           38.6          27.4           38.6
   NOX   BACKGRD METER READING/SCALE             .8/2          .6/2           .8/2
   NOX   BACKGRD PPM                             .8            .6             .8

   HC    CONCENTRATION PPM                       54            48             54
   CO    CONCENTRATION PPM                       90            73             90
   CO2   CONCENTRATION PCT                     1.48          1.03           1.48
   NOX   CONCENTRATION PPM                     37.9          26.8           37.9
   HC    MASS GRAMS                            1.74          2.69           1.74
   CO    MASS GRAMS                            5.87          8.18           5.87
   CO2   MASS GRAMS                         1531.45       1817.47        1531.45
   NOX   MASS GRAMS                            3.63          4.41           3.63
    HC    MASS MG                              1.74          2.69           1.74

   WEIGHTED MASS HC        .37 GRAMS/KILOMETRE
   WEIGHTED MASS CO       1.16 GRAMS/KILOMETRE
   WEIGHTED MASS CO2    277.52 GRAMS/KILOMETRE
   WEIGHTED MASS NOX       .67 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION = 10.39 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =    208.7 STD. CU. METRES
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                               TABLE  E-8                VEHICLE EMISSION RESULTS
                                       1975  LIGHT DUTY EMISSIONS TEST
                                                                                                        YR. 1976
UNIT NO.              TEST NO. 1     Run 5  DATE 10/19/76                  MFGR. CODE   -0             ROAD LOAD    9.5 KW
VEHICLE MODEL  OLDS DIESEL CTLS             ENGINE    5.74 LITRE 8 CYL.    TEST WT.   2041 KG
TEST TYPE  3J29R6M181269                    COMMENTS   1975 FTP  2 Bag Hot
                                                                        WET BULB TEMP  15.0 DEG. C
BAROMETER 745.49 MM OF HG.                                               ABS. HUMIDITY   8.0 MILLIGRAMS/KG
DRY BULB TEMP.    21.7 DEG. C
REL. HUMIDITY      49 PCT.
EXHAUST EMISSIONS
                                                                        BLOWER INLET PRESS., G1 266.7 MM. H2O
    BLOWER DIF. PRESS., G2, 304.8 MM. H2O                               BLOWER INLET TEMP.    43 DEG. C

    BAG RESULTS
    BAG NO.                                          1             2             3
    BLOWER REVOLUTIONS                            7505         12900          7505
    HC    SAMPLE  METER READING/SCALE           15.0/3        12.9/3        15.0/3
    HC    SAMPLE  PPM                              60            52            60
    HC    BACKGRD METER READING/SCALE            1.7/3         1.3/3         1.7/3
    HC    BACKGRD PPM                               7             5             7
    CO    SAMPLE  METER READING/SCALE           43.8/*        36.0/*        43.8/*
    CO    SAMPLE  PPM                              93            74            93
    CO    BACKGRD METER READING/SCALE            1.0/*          .3/*         1.0/*
    CO    BACKGRD PPM                               2             1             2
    CO2   SAMPLE  METER READING/SCALE           36.4/2        26.0/2        36.4/2
    CO2   SAMPLE  PERCENT                        1.56          1.06          1.56
    CO2   BACKGRD METER READING/SCALE            2.0/2         1.9/2         2.0/2
    CO2   BACKGRD PERCENT                         .07           .07           .07
    NOX   SAMPLE  METER READING/SCALE           40.5/2        27.4/2        40.5/2
    NOX   SAMPLE  PPM                            40.5          27.4          40.5
    NOX   BACKGRD METER READING/SCALE             .8/2          .7/2          .8/2
    NOX   BACKGRD PPM                              .8            .7            .8

    HC    CONCENTRATION PPM                        54            47            54
    CO    CONCENTRATION PPM                        87            71            87
    CO2   CONCENTRATION PCT                      1.49           .99          1.49
    NOX   CONCENTRATION PPM                      39.8          26.8          39.8
    HC    MASS GRAMS                             1.74          2.60          1.74
    CO    MASS GRAMS                             5.67          7.99          5.67
    CO2   MASS GRAMS                          1537.34       1759.32       1537.34
    NOX   MASS GRAMS                             3.91          4.52          3.91
     HC    MASS MG                               1.74          2.60          1.74

    WEIGHTED MASS HC        .36 GRAMS/KILOMETRE
    WEIGHTED MASS CO       1.13 GRAMS/KILOMETRE
    WEIGHTED MASS CO2    273.18 GRAMS/KILOMETRE
    WEIGHTED MASS NOX       .70 GRAMS/KILOMETRE

   CARBON BALANCE FUEL CONSUMPTION = 10.23 LITRES PER HUNDRED KILOMETRES
   TOTAL CVS FLOW =    208.5 STD. CU. METRES
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          TABLE E-9     EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                                  VEHICLE NUMBER

     DATE 10/19/76                  TIME     -0 HRS.          TEST NO.  1
     MODEL  1976 OLDS DIESEL CTLSET-7                         ENGINE 5.7 LITRE V  8 CYL.
     DRIVER   DT                    TEST WT.  2041 KG.        GVW     0 KG
     WET BULB TEMP  15 C            DRY BULB TEMP  23 C       REL. HUM.  40.1 PCT
     SPEC. HUM.    7.3 GRAM/KG      BARO.  745.7 MM  HG.      MEASURED FUEL  0.00 KG

       RUN DURATION           23.32 MINUTES
       BLOWER INLET PRESS. 266.7  MM. H2O
       BLOWER DIF.  PRESS. 304.8  MM  H2O
       BLOWER INLET TEMP.     43  DEG. C
       DYNO REVOLUTIONS    22073
       BLOWER REVOLUTIONS     20799
       BLOWER CU. CM /REV.  8442

       BAG RESULTS
        HC  SAMPLE  METER READING/SCALE            19.3/3
        HC  SAMPLE  PPM                              77
        HC  BACKGRD METER READING/SCALE             1.8/3
        HC  BACKGRD PPM                               7
        CO  SAMPLE  METER READING/SCALE            49.4/*
        CO  SAMPLE  PPM                             106
        CO  BACKGRD METER READING/SCALE              .6/*
        CO  BACKGRD PPM                               1
        CO2 SAMPLE  METER READING/SCALE            41.8/2
        CO2 SAMPLE  PERCENT                        1.83
        CO2 BACKGRD METER READING/SCALE             2.3/2
        CO2 BACKGRD PERCENT                         .08
        NOX SAMPLE  METER READING/SCALE            51.9/2
        NOX SAMPLE  PPM                            51.9
        NOX BACKGRD METER READING/SCALE              .9/2
        NOX BACKGRD PPM                              .9
        HC  CONCENTRATION PPM                        71
        CO  CONCENTRATION PPM                       100
        CO2 CONCENTRATION PCT                      1.76
        NOX CONCENTRATION PPM                      51.1
        SO2 COCENTRATION PPM                        0.0
        HC  MASS (GRAMS)                           6.35
        CO  MASS (GRAMS)                          18.12
        CO2 MASS (GRAMS)                        5034.75
        NOX MASS (GRAMS)                          13.64
        SO2 MASS (GRAMS)                           0.00

     HC  GRAMS/KILOMETRE      .29
     CO  GRAMS/KILOMETRE      .83
     CO2 GRAMS/KILOMETRE   232
     NOX GRAMS/KILOMETRE      .63
     SO2 GRAMS/KILOMETRE     0.00

     HC  GRAMS/KG OF FUEL   3.92     HC  GRAMS/MIN       .3
     CO  GRAMS/KG OF FUEL   11.2     CO  GRAMS/MIN      .8
     CO2 GRAMS/KG OF FUEL   3108     CO2 GRAMS/MIN     216
     NOX GRAMS/KG OF FUEL   8.42     NOX GRAMS/MIN     .59
     SO2 GRAMS/KG OF FUEL   0.00     SO2 GRAMS/MIN    0.00

     CARBON BALANCE FUEL CONSUMPTION =  8.85 LITRES PER HUNDRED KILOMETRES
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          TABLE E-10   EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                                 VEHICLE NUMBER

DATE 10/19/76                  TIME    -0 HRS.         TEST NO.  1
MODEL  1976 OLDS DIESEL CTLHFET                        ENGINE 5.7 LITRE V  8 CYL.
DRIVER   DT                    TEST WT.  2041 KG.      GVW    0 KG
WET BULB TEMP  15 C            DRY BULB TEMP  24 C     REL. HUM.  37.5 PCT
SPEC. HUM.    7.0 GRAM/KG      BARO.  745.7 MM  HG.    MEASURED FUEL  0.00 KG

  RUN DURATION           12.77 MINUTES
  BLOWER INLET PRESS. 266.7  MM. H2O
  BLOWER DIF.  PRESS. 304.8  MM  H2O
  BLOWER INLET TEMP.     48  DEG. C
  DYNO REVOLUTIONS    24111
  BLOWER REVOLUTIONS    11387
  BLOWER CU. CM /REV.  8409

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE             21.4/3
   HC  SAMPLE  PPM                                86
   HC  BACKGRD METER READING/SCALE              1.8/3
   HC  BACKGRD PPM                                 7
   CO  SAMPLE  METER READING/SCALE             53.5/*
   CO  SAMPLE  PPM                               116
   CO  BACKGRD METER READING/SCALE               .4/*
   CO  BACKGRD PPM                                 1
   CO2 SAMPLE  METER READING/SCALE             49.4/2
   CO2 SAMPLE  PERCENT                          2.25
   CO2 BACKGRD METER READING/SCALE              2.0/2
   CO2 BACKGRD PERCENT                           .07
   NOX SAMPLE  METER READING/SCALE             71.6/2
   NOX SAMPLE  PPM                              71.6
   NOX BACKGRD METER READING/SCALE               .9/2
   NOX BACKGRD PPM                                .9
   HC  CONCENTRATION PPM                          80
   CO  CONCENTRATION PPM                         109
   CO2 CONCENTRATION PCT                        2.19
   NOX CONCENTRATION PPM                        70.9
   SO2 COCENTRATION PPM                          0.0
   HC  MASS (GRAMS)                             3.82
   CO  MASS (GRAMS)                            10.59
   CO2 MASS (GRAMS)                          3351.14
   NOX MASS (GRAMS)                            10.06
   SO2 MASS (GRAMS)                             0.00

 HC  GRAMS/KILOMETRE       .23
 CO  GRAMS/KILOMETRE       .64
 CO2 GRAMS/KILOMETRE    203
 NOX GRAMS/KILOMETRE       .61
 SO2 GRAMS/KILOMETRE      0.00

 HC  GRAMS/KG OF FUEL   3.55     HC  GRAMS/MIN       .3
 CO  GRAMS/KG OF FUEL    4.8     CO  GRAMS/MIN      .8
 CO2 GRAMS/KG OF FUEL   3111     CO2 GRAMS/MIN     262
 NOX GRAMS/KG OF FUEL   9.34     NOX GRAMS/MIN     .79
 SO2 GRAMS/KG OF FUEL   0.00     SO2 GRAMS/MIN    0.00

 CARBON BALANCE FUEL CONSUMPTION =  7.76 LITRES PER HUNDRED KILOMETRES
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                                TABLE  E-11              VEHICLE EMISSION RESULTS
                                    1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.              TEST NO. 2        DATE 10/20/76                MFGR. CODE   -0               YR. 1976
VEHICLE MODEL  OLDS DIESEL CTLS         ENGINE   5.74 LITRE 8 CYL.   TEST WT.  2041 KG             ROAD LOAD   9.5 KW
TEST TYPE  3J29R6M181269                COMMENTS  COLD-LA-4

BAROMETER 743.46 MM OF HG.                                    WET BULB TEMP  12.8 DEG. C
DRY BULB TEMP.   23.3 DEG. C                                   ABS. HUMIDITY   4.9 MILLIGRAMS/KG
REL. HUMIDITY     27 PCT.
EXHAUST EMISSIONS

                                                              BLOWER INLET PRESS., G1 254.0 MM. H2O
   BLOWER DIF. PRESS., G2, 304.8 MM. H2O                      BLOWER INLET TEMP.   46 DEG. C

   BAG RESULTS
   BAG NO.                                     1            2            3
   BLOWER REVOLUTIONS                       7504        12910         7501
   HC   SAMPLE  METER READING/SCALE       17.0/4        7.0/4       15.6/3
   HC   SAMPLE  PPM                         136           56           63
   HC   BACKGRD METER READING/SCALE         .3/4         .7/4        1.1/3
   HC   BACKGRD PPM                           2            6            4
   CO   SAMPLE  METER READING/SCALE       61.7/*       36.3/*       44.1/*
   CO   SAMPLE  PPM                         137           75           93
   CO   BACKGRD METER READING/SCALE         .6/*         .5/*         .9/*
   CO   BACKGRD PPM                           1            1            2
   CO2  SAMPLE  METER READING/SCALE       44.1/2       27.1/2       36.7/2
   CO2  SAMPLE  PERCENT                    1.96         1.11         1.57
   CO2  BACKGRD METER READING/SCALE        2.2/2        2.4/2        1.6/2
   CO2  BACKGRD PERCENT                     .08          .09          .06
   NOX  SAMPLE  METER READING/SCALE       47.0/2       27.4/2       44.6/2
   NOX  SAMPLE  PPM                        47.0         27.4         44.6
   NOX  BACKGRD METER READING/SCALE        1.0/2         .5/2         .5/2
   NOX  BACKGRD PPM                         1.0           .5           .5

   HC   CONCENTRATION PPM                   134           51           59
   CO   CONCENTRATION PPM                   130           72           88
   CO2  CONCENTRATION PCT                  1.89         1.03         1.52
   NOX  CONCENTRATION PPM                  46.1         26.9         44.2
   HC   MASS GRAMS                         4.28         2.79         1.87
   CO   MASS GRAMS                         8.36         7.99         5.69
   CO2  MASS GRAMS                      1922.58      1799.05      1546.45
   NOX  MASS GRAMS                         4.10         4.12         3.92
    HC   MASS MG                           4.28         2.79         1.87

   WEIGHTED MASS HC        .47 GRAMS/KILOMETRE
   WEIGHTED MASS CO       1.23 GRAMS/KILOMETRE
   WEIGHTED MASS CO2    290.64 GRAMS/KILOMETRE
   WEIGHTED MASS NOX       .67 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION = 10.88 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =    206.0 STD. CU. METRES
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TABLE E-12 VEHICLE EMISSION RESULTS
1975 LIGHT DUTY EMISSIONS TEST

UNIT NO. TEST NO. 2
VEHICLE MODEL OLDS DIESEL CTLS
TEST TYPE 3J29R6M181269

DATE 10/20/76
ENGINE 5.74 LITRE 8 CYL.
COMMENTS 1975 FTP 2 BAG COLD

MFGR. CODE -0
TEST WT. 2041 KG

YR. 1976
ROAD LOAD 9.5 KW

BAROMETER 743.46 MM OF HG.
DRY BULB TEMP. 23.3 DEG. C
REL. HUMIDITY 27 PCT.
EXHAUST EMISSIONS

WET BULB TEMP 12.8 DEG. C
ABS. HUMIDITY 4.9 MILLIGRAMS/KG

BLOWER INLET PRESS., G1 254.0 MM. H2O
BLOWER INLET TEMP. 46 DEG. C

BLOWER DIF. PRESS., G2, 304.8 MM. H2O

BAG RESULTS			
BAG NO.	1	2	3
BLOWER REVOLUTIONS	7504	12910	7504
HC SAMPLE METER READING/SCALE	17.0/4	7.0/4	17.0/4
HC SAMPLE PPM	136	56	136
HC BACKGRD METER READING/SCALE	.3/4	.7/4	.3/4
HC BACKGRD PPM	2	6	2
CO SAMPLE METER READING/SCALE	61.7/*	36.3/*	61.7/*
CO SAMPLE PPM	137	75	137
CO BACKGRD METER READING/SCALE	.6/*	.5/*	.6/*
CO BACKGRD PPM	1	1	1
CO2 SAMPLE METER READING/SCALE	44.1/2	27.1/2	44.1/2
CO2 SAMPLE PERCENT	1.96	1.11	1.96
CO2 BACKGRD METER READING/SCALE	2.2/2	2.4/2	2.2/2
CO2 BACKGRD PERCENT	.08	.09	.08
NOX SAMPLE METER READING/SCALE	47.0/2	27.4/2	47.0/2
NOX SAMPLE PPM	47.0	27.4	47.0
NOX BACKGRD METER READING/SCALE	1.0/2	.5/2	1.0/2
NOX BACKGRD PPM	1.0	.5	1.0
HC CONCENTRATION PPM	134	51	134
CO CONCENTRATION PPM	130	72	130
CO2 CONCENTRATION PCT	1.89	1.03	1.89
NOX CONCENTRATION PPM	46.1	26.9	46.1
HC MASS GRAMS	4.28	2.79	4.28
CO MASS GRAMS	8.36	7.99	8.36
CO2 MASS GRAMS	1922.58	1799.05	1922.58
NOX MASS GRAMS	4.10	4.12	4.10
HC MASS MG	4.28	2.79	4.28

WEIGHTED MASS HC	.59	GRAMS/KILOMETRE
WEIGHTED MASS CO	1.35	GRAMS/KILOMETRE
WEIGHTED MASS CO2	308.40	GRAMS/KILOMETRE
WEIGHTED MASS NOX	.68	GRAMS/KILOMETRE

CARBON BALANCE FUEL CONSUMPTION = 11.55 LITRES PER HUNDRED KILOMETRES
TOTAL CVS FLOW = 206.0 STD. CU. METRES

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                    TABLE   E-13             VEHICLE EMISSION RESULTS
                         1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.            TEST NO. 2        DATE 10/20/76                  MFGR. CODE   -0             YR. 1976
VEHICLE MODEL  OLDS DIESEL CTLS       ENGINE   5.74 LITRE 8 CYL.     TEST WT.  2041 KG           ROAD LOAD   9.5 KW
TEST TYPE  3J29R6M181269              COMMENTS  1975 FTP 2 BAG HOT

BAROMETER 743.46 MM OF HG.                                           WET BULB TEMP  13.3 DEG. C
DRY BULB TEMP.   23.9 DEG. C                                          ABS. HUMIDITY   5.2 MILLIGRAMS/KG
REL. HUMIDITY     28 PCT.
EXHAUST EMISSIONS
                                                                     BLOWER INLET PRESS., G1 261.6 MM. H2O
   BLOWER DIF. PRESS., G2, 315.0 MM. H2O                             BLOWER INLET TEMP.   45 DEG. C

   BAG RESULTS
   BAG NO.                                      1            2            3
   BLOWER REVOLUTIONS                          7501        12913         7501
   HC   SAMPLE  METER READING/SCALE           15.6/3       12.8/3       15.6/3
   HC   SAMPLE  PPM                            63           51           63
   HC   BACKGRD METER READING/SCALE            1.1/3        1.1/3        1.1/3
   HC   BACKGRD PPM                             4            4            4
   CO   SAMPLE  METER READING/SCALE           44.1/*       35.8/*       44.1/*
   CO   SAMPLE  PPM                            93           74           93
   CO   BACKGRD METER READING/SCALE             .9/*         .3/*         .9/*
   CO   BACKGRD PPM                             2            1            2
   CO2  SAMPLE  METER READING/SCALE           36.7/2       26.1/2       36.7/2
   CO2  SAMPLE  PERCENT                        1.57         1.06         1.57
   CO2  BACKGRD METER READING/SCALE            1.6/2        1.3/2        1.6/2
   CO2  BACKGRD PERCENT                         .06          .05          .06
   NOX  SAMPLE  METER READING/SCALE           44.6/2       28.7/2       44.6/2
   NOX  SAMPLE  PPM                           44.6         28.7         44.6
   NOX  BACKGRD METER READING/SCALE             .5/2         .6/2         .5/2
   NOX  BACKGRD PPM                             .5           .6           .5

   HC   CONCENTRATION PPM                      59           47           59
   CO   CONCENTRATION PPM                      88           71           88
   CO2  CONCENTRATION PCT                      1.52         1.02         1.52
   NOX  CONCENTRATION PPM                     44.2         28.1         44.2
   HC   MASS GRAMS                             1.87         2.58         1.87
   CO   MASS GRAMS                             5.69         7.90         5.69
   CO2  MASS GRAMS                          1545.94      1782.46      1545.94
   NOX  MASS GRAMS                             3.96         4.34         3.96
    HC   MASS MG                               1.87         2.58         1.87

   WEIGHTED MASS HC        .37 GRAMS/KILOMETRE
   WEIGHTED MASS CO       1.13 GRAMS/KILOMETRE
   WEIGHTED MASS CO2    275.81 GRAMS/KILOMETRE
   WEIGHTED MASS NOX       .69 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION = 10.33 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =   205.9 STD. CU. METRES
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     TABLE   E-14  EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                             VEHICLE NUMBER

DATE 10/20/76                 TIME     -0 HRS.        TEST NO.  2
MODEL  1976 OLDS DIESEL CTLSET-7                      ENGINE 5.7 LITRE V  8 CYL.
DRIVER   DT                   TEST WT.  2041 KG.      GVW    0 KG
WET BULB TEMP  13 C           DRY BULB TEMP  22 C     REL. HUM.  34.2 PCT
SPEC. HUM.   5.6 GRAM/KG      BARO.  743.5 MM  HG.    MEASURED FUEL  0.00 KG

  RUN DURATION           23.25 MINUTES
  BLOWER INLET PRESS. 254.0  MM. H2O
  BLOWER DIF.  PRESS. 304.8  MM  H2O
  BLOWER INLET TEMP.      48  DEG. C
  DYNO REVOLUTIONS     32000
  BLOWER REVOLUTIONS     20731
  BLOWER CU. CM /REV.  8408

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE            17.0/3
   HC   SAMPLE  PPM                              68
   HC   BACKGRD METER READING/SCALE              .9/3
   HC   BACKGRD PPM                               4
   CO   SAMPLE  METER READING/SCALE            47.2/*
   CO   SAMPLE  PPM                             101
   CO   BACKGRD METER READING/SCALE             1.1/*
   CO   BACKGRD PPM                               2
   CO2  SAMPLE  METER READING/SCALE            40.5/2
   CO2  SAMPLE  PERCENT                        1.77
   CO2  BACKGRD METER READING/SCALE             1.2/2
   CO2  BACKGRD PERCENT                         .04
   NOX  SAMPLE  METER READING/SCALE            53.5/2
   NOX  SAMPLE  PPM                            53.5
   NOX  BACKGRD METER READING/SCALE              .8/2
   NOX  BACKGRD PPM                              .8
   HC   CONCENTRATION PPM                        65
   CO   CONCENTRATION PPM                        95
   CO2  CONCENTRATION PCT                      1.73
   NOX  CONCENTRATION PPM                      52.8
   SO2  COCENTRATION PPM                       0.0
   HC   MASS (GRAMS)                           5.66
   CO   MASS (GRAMS)                          16.67
   CO2  MASS (GRAMS)                        4808.55
   NOX  MASS (GRAMS)                          13.08
   SO2  MASS (GRAMS)                           0.00

 HC  GRAMS/KILOMETRE       .26
 CO  GRAMS/KILOMETRE       .77
 CO2 GRAMS/KILOMETRE    221
 NOX GRAMS/KILOMETRE       .60
 SO2 GRAMS/KILOMETRE      0.00

 HC   GRAMS/KG OF FUEL   3.66    HC   GRAMS/MIN        .2
 CO   GRAMS/KG OF FUEL   10.8    CO   GRAMS/MIN       .7
 CO2  GRAMS/KG OF FUEL   3109    CO2  GRAMS/MIN     207
 NOX  GRAMS/KG OF FUEL   8.46    NOX  GRAMS/MIN     .56
 SO2  GRAMS/KG OF FUEL   0.00    SO2  GRAMS/MIN    0.00

 CARBON BALANCE FUEL CONSUMPTION =  8.45 LITRES PER HUNDRED KILOMETRES
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      TABLE E-15   EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                         VEHICLE NUMBER

DATE 10/20/76                TIME     -0 HRS.         TEST NO. 2
MODEL  1976 OLDS DIESEL CTLFET                         ENGINE 5.7 LITRE V  8 CYL.
DRIVER    DT                 TEST WT.  2041 KG.       GVW    0 KG
WET BULB TEMP  12 C          DRY BULB TEMP  22 C      REL. HUM.  28.3 PCT
SPEC. HUM.   4.8 GRAM/KG     BARO.  743.5 MM  HG.     MEASURED FUEL  0.00 KG

  RUN DURATION          12.77 MINUTES
  BLOWER INLET PRESS. 261.6  MM. H2O
  BLOWER DIF.  PRESS. 312.4  MM  H2O
  BLOWER INLET TEMP.     48  DEG. C
  DYNO REVOLUTIONS    24110
  BLOWER REVOLUTIONS    11387
  BLOWER CU. CM /REV.  8397

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE           20.6/3
   HC   SAMPLE  PPM                             83
   HC   BACKGRD METER READING/SCALE            2.3/3
   HC   BACKGRD PPM                              9
   CO   SAMPLE  METER READING/SCALE           51.9/*
   CO   SAMPLE  PPM                            112
   CO   BACKGRD METER READING/SCALE             .9/*
   CO   BACKGRD PPM                              2
   CO2 SAMPLE  METER READING/SCALE            47.2/2
   CO2 SAMPLE  PERCENT                        2.13
   CO2 BACKGRD METER READING/SCALE            1.6/2
   CO2 BACKGRD PERCENT                         .06
   NOX SAMPLE  METER READING/SCALE            68.8/2
   NOX SAMPLE  PPM                            68.8
   NOX BACKGRD METER READING/SCALE              .9/2
   NOX BACKGRD PPM                              .9
   HC   CONCENTRATION PPM                       75
   CO   CONCENTRATION PPM                      105
   CO2 CONCENTRATION PCT                      2.08
   NOX CONCENTRATION PPM                      68.0
   SO2 COCENTRATION PPM                       0.0
   HC   MASS (GRAMS)                          3.58
   CO   MASS (GRAMS)                         10.17
   CO2 MASS (GRAMS)                        3167.99
   NOX MASS (GRAMS)                           9.04
   SO2 MASS (GRAMS)                           0.00

HC  GRAMS/KILOMETRE       .22
CO  GRAMS/KILOMETRE       .62
CO2 GRAMS/KILOMETRE   192
NOX GRAMS/KILOMETRE       .55
SO2 GRAMS/KILOMETRE      0.00

HC  GRAMS/KG OF FUEL   3.51     HC  GRAMS/MIN        .3
CO  GRAMS/KG OF FUEL   10.0     CO  GRAMS/MIN       .8
CO2 GRAMS/KG OF FUEL   3111     CO2 GRAMS/MIN     248
NOX GRAMS/KG OF FUEL   8.87     NOX GRAMS/MIN     .71
SO2 GRAMS/KG OF FUEL   0.00     SO2 GRAMS/MIN    0.00

CARBON BALANCE FUEL CONSUMPTION =  7.34 LITRES PER HUNDRED KILOMETRES
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                        TABLE  E-16              VEHICLE EMISSION RESULTS
                              1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.              TEST NO. 3         DATE 10/21/76                  MFGR. CODE   =0               YR. 1976
VEHICLE MODEL  OLDS DIESEL CTLS          ENGINE    5.74 LITRE 8 CYL.    TEST WT.  2041 KG             ROAD LOAD    9.5 KW
TEST TYPE  3J29R6M181269                 COMMENTS  1975 FTP 3 BAG COLD

BAROMETER 747.52 MM OF HG.                                              WET BULB TEMP  16.1 DEG. C
DRY BULB TEMP.    22.2 DEG. C                                            ABS. HUMIDITY   9.0 MILLIGRAMS/KG
REL. HUMIDITY      53 PCT.
EXHAUST EMISSIONS

                                                                        BLOWER INLET PRESS., G1 254.0 MM. H20
    BLOWER DIF. PRESS., G2, 304.8 MM. H20                                BLOWER INLET TEMP.    44 DEG. C

    BAG RESULTS
    BAG NO.                                       1              2              3
    BLOWER REVOLUTIONS                           7516          12893           7518
    HC    SAMPLF  METER READING/SCALE            16.8/4          6.9/4         16.4/3
    HC    SAMPLE  PPM                            135             55             66
    HC    BACKGRD METER READING/SCALE             .9/4          1.2/4          2.3/3
    HC    BACKGRD PPM                              7             10              9
    CO    SAMPLE  METER READING/SCALE            59.8/*         35.5/*         44.1/*
    CO    SAMPLE  PPM                            132             73             93
    CO    BACKGRD METER READING/SCALE             .5/*           .2/*           .9/*
    CO    BACKGRD PPM                              1              0              2
    CO2   SAMPLE  METER READING/SCALE            42.1/2         26.2/2         36.3/2
    CO2   SAMPLE  PERCENT                        1.85           1.07           1.55
    CO2   BACKGRD METER READING/SCALE             2.4/2          2.2/2          1.7/2
    CO2   BACKGRD PERCENT                         .09            .08            .06
    NOX   SAMPLE  METER READING/SCALE            42.2/2         26.7/2         42.6/2
    NOX   SAMPLE  PPM                            42.2           26.7           42.6
    NOX   BACKGRD METER READING/SCALE              .6/2           .6/2           .9/2
    NOX   BACKGRD PPM                               .6             .6             .9

    HC    CONCENTRATION PPM                       128             46             57
    CO    CONCENTRATION PPM                       124             70             88
    CO2   CONCENTRATION PCT                       1.77           .99           1.50
    NOX   CONCENTRATION PPM                       41.7           26.1           41.8
    HC    MASS GRAMS                              4.16           2.57           1.86
    CO    MASS GRAMS                              8.13           7.86           5.73
    CO2   MASS GRAMS                            1832.03        1756.79        1544.89
    NOX   MASS GRAMS                              4.23           4.56           4.25
     HC    MASS MG                                4.16           2.57           1.86

    WEIGHTED MASS HC        .45 GRAMS/KILOMETRE
    WEIGHTED MASS CO       1.21 GRAMS/KILOMETRE
    WEIGHTED MASS CO2    283.83 GRAMS/KILOMETRE
    WEIGHTED MASS NOX       .73 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION = 10.63 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =   208.6 STD. CU. METRES
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                    TARLE  E-17                  VEHICLE EMISSION RESULTS
                           1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.              TEST NO. 3        DATE 10/21/76                  MFGR. CODE   -0                YR. 1976
VEHICLE MODEL  OLDS DIESEL CTLS         ENGINE   5.74 LITRE 8 CYL.     TEST WT.  2041 KG              ROAD LOAD   9.5 KW
TEST TYPE  3J29R6M181269                COMMENTS  1975 FTP 2 BAG COLD

BAROMETER 747.52 MM OF HG.                                             WET BULB TEMP  16.1 DEG. C
DRY BULB TEMP.   22.2 DEG. C                                            ABS. HUMIDITY   9.0 MILLIGRAMS/KG
REL. HUMIDITY     53 PCT.
EXHAUST EMISSIONS

                                                                       BLOWER INLET PRESS., G1 254.0 MM. H20
   BLOWER DIF. PRESS., G2, 304.8 MM. H20                               BLOWER INLET TEMP.    44 DEG. C

   BAG RESULTS
   BAG NO.                                       1               2               3
   BLOWER REVOLUTIONS                          7516           12893           7516
   HC   SAMPLE  METFR READING/SCALE           16.8/4           6.9/4          16.8/4
   HC   SAMPLE  PPM                            135              55             135
   HC   BACKGRD METER READING/SCALE             .9/4           1.2/4            .9/4
   HC   BACKGRD PPM                              7              10               7
   CO   SAMPLE  METER READING/SCALE           59.8/*          35.5/*          59.8/*
   CO   SAMPLE  PPM                            132              73             132
   CO   BACKGRD METER READING/SCALE             .5/*            .2/*            .5/*
   CO   BACKGRD PPM                              1               0               1
   CO2  SAMPLE  METER READING/SCALE           42.1/2          26.2/2          42.1/2
   CO2  SAMPLF  PERCENT                       1.85            1.07            1.85
   CO2  BACKGRD METER READING/SCALE            2.4/2           2.2/2           2.4/2
   CO2  BACKGRD PERCENT                        .09             .08             .09
   NOX  SAMPLE  METER READING/SCALE           42.2/2          26.7/2          42.2/2
   NOX  SAMPLE  PPM                           42.2            26.7            42.2
   NOX  BACKGRD METER READING/SCALE             .6/2            .6/2            .6/2
   NOX  BACKGRD PPM                              .6              .6              .6

   HC   CONCENTRATION PPM                      128              46             128
   CO   CONCENTRATION PPM                      124              70             124
   CO2  CONCENTRATION PCT                     1.77             .99            1.77
   NOX  CONCENTRATION PPM                     41.7            26.1            41.7
   HC   MASS GRAMS                            4.16            2.57            4.16
   CO   MASS GRAMS                            8.13            7.86            8.13
   CO2  MASS GRAMS                         1832.03         1756.79         1832.03
   NOX  MASS GRAMS                            4.23            4.56            4.23
    HC   MASS MG                              4.16            2.57            4.16

   WEIGHTED MASS HC        .56 GRAMS/KILOMETRE
   WEIGHTED MASS CO       1.33 GRAMS/KILOMETRE
   WEIGHTED MASS CO2    297.40 GRAMS/KILOMETRE
   WEIGHTED MASS NOX       .73 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION = 11.14 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =   208.6 STD. CU. METRES
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                     TABLE  E-18             VEHICLE EMISSION RESULTS
                        1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.            TEST NO. 3    Run 1 DATE 10/21/76              MFGR. CODE   -0          YR. 1976
VEHICLE MODEL  OLDS DIESEL CTLS         ENGINE   5,74 LITRE 8 CYL.  TEST WT.  2041 KG       ROAD LOAD   9.5 KW
TEST TYPE  3J29R6M181269                COMMENTS  1975 FTP 2 BAG HOT

BAROMETER 747,52 MM OF HG.                                          WET BULB TEMP  15,6 DEG. C
DRY BULB TEMP.    23,3 DEG. C                                        ABS. HUMIDITY   7,9 MILLIGRAMS/KG
REL. HUMIDITY      43 PCT.
EXHAUST EMISSIONS
                                                                    BLOWER INLET PRESS., G1 254.0 MM. H2O
    BLOWER DIF. PRESS., G2, 304,8 MM. H2O                           BLOWER INLET TEMP.    43 DEG. C

    BAG RESULTS
    BAG NO.                                    1            2            3
    BLOWER REVOLUTIONS                       7518         12903        7518
    HC   SAMPLE  METER READING/SCALE         16,4/3       13,9/3       16,4/3
    HC   SAMPLE  PPM                           66           56           66
    HC   BACKGRD METER READING/SCALE          2,3/3        2,3/3        2,3/3
    HC   BACKGRD PPM                            9            9            9
    CO   SAMPLE  METER READING/SCALE         44,1/*       36,4/*       44,1/*
    CO   SAMPLE  PPM                           93           75           93
    CO   BACKGRD METER READING/SCALE           .9/*        1,1/*         .9/*
    CO   BACKGRD PPM                            2            2            2
    CO2  SAMPLE  METER READING/SCALE         36,3/2       26,0/2       36,3/2
    CO2  SAMPLE  PERCENT                     1,55         1,06         1,55
    CO2  BACKGRD METER READING/SCALE          1,7/2        1,9/2        1,7/2
    CO2  BACKGRD PERCENT                      .06          .07          .06
    NOX  SAMPLE  METER READING/SCALE         42,6/2       28,7/2       42,6/2
    NOX  SAMPLE  PPM                         42,6         28,7         42,6
    NOX  BACKGRD METER READING/SCALE           .9/2         .9/2         .9/2
    NOX  BACKGRD PPM                           .9           .9           .9

    HC   CONCENTRATION PPM                     57           47           57
    CO   CONCENTRATION PPM                     88           71           88
    CO2  CONCENTRATION PCT                   1.50          .99         1.50
    NOX  CONCENTRATION PPM                   41,8         27,9         41,8
    HC   MASS GRAMS                          1,87         2,64         1,87
    CO   MASS GRAMS                          5,77         8,00         5,77
    CO2  MASS GRAMS                       1551,44      1767,32      1551,44
    NOX  MASS GRAMS                          4,12         4,72         4,12
     HC   MASS MG                            1,87         2,64         1,87

    WEIGHTED MASS HC        .37 GRAMS/KILOMETRE
    WEIGHTED MASS CO       1,14 GRAMS/KILOMETRE
    WEIGHTED MASS CO2    275,02 GRAMS/KILOMETRE
    WEIGHTED MASS NOX       .73 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION = 10,30 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =   209,6 STD. CU. METRES
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                         TABLE  E-19              VEHICLE EMISSION RESULTS
                              1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.             TEST NO. 3        DATE 10/21/76                   MFGR. CODE   -0              YR. 1976
VEHICLE MODEL  OLDS DIESEL CTLS        ENGINE   5.74 LITRE 8 CYL.      TEST WT.  2041 KG            ROAD LOAD   9.5 KW
TEST TYPE  3J29R6M181269               COMMENTS  1975 FTP 2 BAG HOT RUN 2

BAROMETER 747.52 MM OF HG.                                             WET BULB TEMP  16.1 DEG. C
DRY BULB TEMP.   22.8 DEG. C                                            ABS. HUMIDITY   8.7 MILLIGRAMS/KG
REL. HUMIDITY     50 PCT.
EXHAUST EMISSIONS
                                                                       BLOWER INLET PRESS., G1 254.0 MM. H2O
   BLOWER DIF. PRESS., G2, 304.8 MM. H2O                               BLOWER INLET TEMP.    43 DEG. C

   BAG RESULTS
   BAG NO.                                         1              2              3
   BLOWER REVOLUTIONS                            7495          12919           7495
   HC    SAMPLE  METER READING/SCALE            15.2/3         12.8/3         15.2/3
   HC    SAMPLE  PPM                              61             51             61
   HC    BACKGRD METER READING/SCALE             1.9/3          1.8/3          1.9/3
   HC    BACKGRD PPM                               8              7              8
   CO    SAMPLE  METER READING/SCALE            41.4/*         33.8/*         41.4/*
   CO    SAMPLE  PPM                              87             69             87
   CO    BACKGRD METER READING/SCALE              .6/*           .5/*           .6/*
   CO    BACKGRD PPM                               1              1              1
   CO2   SAMPLE  METER READING/SCALE            34.8/2         24.6/2         34.8/2
   CO2   SAMPLE  PERCENT                        1.48            .99           1.48
   CO2   BACKGRD METER READING/SCALE             1.4/2          1.5/2          1.4/2
   CO2   BACKGRD PERCENT                         .05            .05            .05
   NOX   SAMPLE  METER READING/SCALE            42.5/2         28.3/2         42.5/2
   NOX   SAMPLE  PPM                            42.5           28.3           42.5
   NOX   BACKGRD METER READING/SCALE              .9/2           .8/2           .9/2
   NOX   BACKGRD PPM                               .9             .8             .9

   HC    CONCENTRATION PPM                        54             44             54
   CO    CONCENTRATION PPM                        82             66             82
   CO2   CONCENTRATION PCT                      1.43            .94           1.43
   NOX   CONCENTRATION PPM                      41.7           27.6           41.7
   HC    MASS GRAMS                             1.75           2.48           1.75
   CO    MASS GRAMS                             5.38           7.46           5.38
   CO2   MASS GRAMS                          1478.95        1679.56        1478.95
   NOX   MASS GRAMS                             4.21           4.80           4.21
    HC    MASS MG                               1.75           2.48           1.75

   WEIGHTED MASS HC        .35 GRAMS/KILOMETRE
   WEIGHTED MASS CO       1.06 GRAMS/KILOMETRE
   WEIGHTED MASS CO2    261.74 GRAMS/KILOMETRE
   WEIGHTED MASS NOX       .75 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION =  9.80 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =   209.4 STD. CU. METRES
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                    TABLE  E-20               VEHICLE EMISSION RESULTS
                        1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.             TEST NO. 3      DATE 10/21/76                 MFGR. CODE   -0           YR. 1976
VEHICLE MODEL  OLDS DIESEL CTLS      ENGINE   5.74 LITRE 8 CYL.    TEST WT.  2041 KG         ROAD LOAD    9.5 KW
TEST TYPE  3J29R6M181269             COMMENTS  1975 FTP 2 BAG HOT RUN 3

BAROMETER 747.27 MM OF HG.                                       WET BULB TEMP  12.8 DEG. C
DRY BULB TEMP.    25.0 DEG. C                                     ABS. HUMIDITY   4.1 MILLIGRAMS/KG
REL. HUMIDITY      21 PCT.
EXHAUST EMISSIONS
                                                                 BLOWER INLET PRESS., G1 254.0 MM. H2O
    BLOWER DIF. PRESS., G2, 304.8 MM. H2O                        BLOWER INLET TEMP.    45 DEG. C

    BAG RESULTS
    BAG NO.                                     1              2              3
    BLOWER REVOLUTIONS                        7518           12890          7518
    HC    SAMPLE  METER READING/SCALE         15.1/3         12.3/3         15.1/3
    HC    SAMPLE  PPM                          60             49             60
    HC    BACKGRD METER READING/SCALE          2.1/3          1.9/3          2.1/3
    HC    BACKGRD PPM                          8              8              8
    CO    SAMPLE  METER READING/SCALE         41.6/*         35.1/*         41.6/*
    CO    SAMPLE  PPM                          87             72             87
    CO    BACKGRD METER READING/SCALE          .5/*           .9/*           .5/*
    CO    BACKGRD PPM                          1              2              1
    CO2   SAMPLE  METER READING/SCALE         34.7/2         26.0/2         34.7/2
    CO2   SAMPLE  PERCENT                     1.47           1.06           1.47
    CO2   BACKGRD METER READING/SCALE          1.3/2          1.6/2          1.3/2
    CO2   BACKGRD PERCENT                      .05            .06            .05
    NOX   SAMPLE  METER READING/SCALE         43.0/2         30.8/2         43.0/2
    NOX   SAMPLE  PPM                         43.0           30.8           43.0
    NOX   BACKGRD METER READING/SCALE          .8/2           .8/2           .8/2
    NOX   BACKGRD PPM                          .8             .8             .8

    HC    CONCENTRATION PPM                    53             42             53
    CO    CONCENTRATION PPM                    84             69             84
    CO2   CONCENTRATION PCT                   1.43           1.00           1.43
    NOX   CONCENTRATION PPM                   42.3           30.1           42.3
    HC    MASS GRAMS                          1.71           2.33           1.71
    CO    MASS GRAMS                          5.45           7.70           5.45
    CO2   MASS GRAMS                       1471.80        1771.38        1471.80
    NOX   MASS GRAMS                          3.72           4.54           3.72
     HC    MASS MG                            1.71           2.33           1.71

    WEIGHTED MASS HC        .33 GRAMS/KILOMETRE
    WEIGHTED MASS CO       1.09 GRAMS/KILOMETRE
    WEIGHTED MASS CO2    268.75 GRAMS/KILOMETRE
    WEIGHTED MASS NOX       .68 GRAMS/KILOMETRE

   CARBON BALANCE FUEL CONSUMPTION = 10.06 LITRES PER HUNDRED KILOMETRES
   TOTAL CVS FLOW =   208.1 STD. CU. METRES
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                          TABLE  E-21                VEHICLE EMISSION RESULTS
                                   1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.               TEST NO. 3          DATE 10/21/76                  MFGR. CODE   -0                 YR. 1976
VEHICLE MODEL  OLDS DIESEL CTLS            ENGINE   5.74 LITRE 8 CYL.     TEST WT.  2041 KG               ROAD LOAD    9.5 KW
TEST TYPE  3J29R6M181269                   COMMENTS  1975 FTP 2 BAG HOT RUN 4

BAROMETER 747.52 MM OF HG.                                                WET BULB TEMP  13.9 DEG. C
DRY BULB TEMP.    26.1 DEG. C                                              ABS. HUMIDITY   4.8 MILLIGRAMS/KG
REL. HUMIDITY      23 PCT.
EXHAUST EMISSIONS

                                                                          BLOWER INLET PRESS., G1 259.1 MM. H2O
    BLOWER DIF. PRESS., G2, 309.9 MM. H2O                                 BLOWER INLET TEMP.    43 DEG. C

    BAG RESULTS
    BAG NO.                                           1             2             3
    BLOWER REVOLUTIONS                              7506         12897          7506
    HC    SAMPLE  METER READING/SCALE               15.7/3        13.5/3        15.7/3
    HC    SAMPLE  PPM                                63            54            63
    HC    BACKGRD METER READING/SCALE                2.5/3         2.3/3         2.5/3
    HC    BACKGRD PPM                                10             9            10
    CO    SAMPLE  METER READING/SCALE               40.7/*        32.7/*        40.7/*
    CO    SAMPLE  PPM                                85            67            85
    CO    BACKGRD METER READING/SCALE                .8/*          .9/*          .8/*
    CO    BACKGRD PPM                                 1             2             1
    CO2   SAMPLE  METER READING/SCALE               33.8/2        24.1/2        33.8/2
    CO2   SAMPLE  PERCENT                           1.43           .97          1.43
    CO2   BACKGRD METER READING/SCALE                1.5/2         2.1/2         1.5/2
    CO2   BACKGRD PERCENT                            .05           .08           .05
    NOX   SAMPLE  METER READING/SCALE               41.2/2        27.1/2        41.2/2
    NOX   SAMPLE  PPM                               41.2          27.1          41.2
    NOX   BACKGRD METER READING/SCALE                1.0/2          .9/2         1.0/2
    NOX   BACKGRD PPM                                1.0            .9           1.0

    HC    CONCENTRATION PPM                           54            45            54
    CO    CONCENTRATION PPM                           81            64            81
    CO2   CONCENTRATION PCT                         1.38           .90          1.38
    NOX   CONCENTRATION PPM                         40.3          26.3          40.3
    HC    MASS GRAMS                                1.74          2.52          1.74
    CO    MASS GRAMS                                5.31          7.16          5.31
    CO2   MASS GRAMS                             1424.58       1598.10       1424.58
    NOX   MASS GRAMS                                3.63          4.07          3.63
     HC    MASS MG                                  1.74          2.52          1.74

    WEIGHTED MASS HC        .35 GRAMS/KILOMETRE
    WEIGHTED MASS CO       1.03 GRAMS/KILOMETRE
    WEIGHTED MASS CO2    250.48 GRAMS/KILOMETRE
    WEIGHTED MASS NOX       .64 GRAMS/KILOMETRE

   CARBON BALANCE FUEL CONSUMPTION =  9.38 LITRES PER HUNDRED KILOMETRES
   TOTAL CVS FLOW =   209.1 STD. CU. METRES
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                         TABLE  E-22             VEHICLE EMISSION RESULTS
                              1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.            TEST NO. 3         DATE 10/21/76                MFGR. CODE   -0               YR. 1976
VEHICLE MODEL  OLDS DIESEL CTLS        ENGINE   5.74 LITRE 8 CYL.   TEST WT.  2041 KG             ROAD LOAD    9.5 KW
TEST TYPE  3J29R6M181269               COMMENTS  1975 FTP 2 BAG HOT RUN 5

BAROMETER 747.52 MM OF HG.                                          WET BULB TEMP  12.8 DEG. C
DRY BULB TEMP.    23.9 DEG. C                                        ABS. HUMIDITY   4.6 MILLIGRAMS/KG
REL. HUMIDITY      25 PCT.
EXHAUST EMISSIONS

                                                                    BLOWER INLET PRESS., G1 254.0 MM. H2O
   BLOWER DIF. PRESS., G2, 304.8 MM. H2O                            BLOWER INLET TEMP.    43 DEG. C

   BAG RESULTS
   BAG NO.                                      1             2             3
   BLOWER REVOLUTIONS                        7508         12913          7508
   HC    SAMPLE  METER READING/SCALE       15.2/3        13.4/3        15.2/3
   HC    SAMPLE  PPM                           61            54            61
   HC    BACKGRD METER READING/SCALE        2.5/3         2.2/3         2.5/3
   HC    BACKGRD PPM                           10             9            10
   CO    SAMPLE  METER READING/SCALE       40.2/*        34.7/*        40.2/*
   CO    SAMPLE  PPM                           84            71            84
   CO    BACKGRD METER READING/SCALE         .8/*          .7/*          .8/*
   CO    BACKGRD PPM                            1             1             1
   CO2   SAMPLE  METER READING/SCALE       33.8/2        26.2/2        33.8/2
   CO2   SAMPLE  PERCENT                     1.43          1.07          1.43
   CO2   BACKGRD METER READING/SCALE        1.9/2         2.2/2         1.9/2
   CO2   BACKGRD PERCENT                      .07           .08           .07
   NOX   SAMPLE  METER READING/SCALE       39.7/2        29.4/2        39.7/2
   NOX   SAMPLE  PPM                         39.7          29.4          39.7
   NOX   BACKGRD METER READING/SCALE         .9/2          .9/2          .9/2
   NOX   BACKGRD PPM                           .9            .9            .9

   HC    CONCENTRATION PPM                     52            46            52
   CO    CONCENTRATION PPM                     80            68            80
   CO2   CONCENTRATION PCT                   1.36           .99          1.36
   NOX   CONCENTRATION PPM                   38.9          28.6          38.9
   HC    MASS GRAMS                          1.68          2.55          1.68
   CO    MASS GRAMS                          5.24          7.69          5.24
   CO2   MASS GRAMS                       1413.54       1767.05       1413.54
   NOX   MASS GRAMS                          3.49          4.41          3.49
    HC    MASS MG                            1.68          2.55          1.68

   WEIGHTED MASS HC        .35 GRAMS/KILOMETRE
   WEIGHTED MASS CO       1.07 GRAMS/KILOMETRE
   WEIGHTED MASS CO2    263.57 GRAMS/KILOMETRE
   WEIGHTED MASS NOX       .65 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION =  9.87 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =   209.5 STD. CU. METRES
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        TABLE  E-23  EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                            VEHICLE NUMBER

DATE 10/21/76                  TIME     -0 HRS.          TEST NO.  3
MODEL  1976 OLDS DIESEL CTLSET 7                         ENGINE 5.7 LITRE    8 CYL.
DRIVER   DT                    TEST WT.  2041 KG.        GVW    0 KG
WET BULB TEMP  13 C            DRY BULB TEMP  24 C       REL. HUM.  24.8 PCT
SPEC. HUM.   4.6 GRAM/KG       BARO.  747.5 MM  HG.      MEASURED FUEL  0.00 KG

  RUN DURATION          23.30 MINUTES
  BLOWER INLET PRESS. 254.1  MM. H2O
  BLOWER DIF.  PRESS. 317.4  MM  H2O
  BLOWER INLET TEMP.      46  DEG. C
  DYNO REVOLUTIONS    31850
  BLOWER REVOLUTIONS    20777
  BLOWER CU. CM /REV.  8417

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE                17.5/3
   HC  SAMPLE  PPM                                  70
   HC  BACKGRD METER READING/SCALE                 2.3/3
   HC  BACKGRD PPM                                   4
   CO  SAMPLE  METER READING/SCALE                47.0/*
   CO  SAMPLE  PPM                                 100
   CO  BACKGRD METER READING/SCALE                  .8/*
   CO  BACKGRD PPM                                   1
   CO2 SAMPLE  METER READING/SCALE                42.2/2
   CO2 SAMPLE  PERCENT                            1.85
   CO2 BACKGRD METER READING/SCALE                 2.0/2
   CO2 BACKGRD PERCENT                             .07
   NOX SAMPLE  METER READING/SCALE                49.3/2
   NOX SAMPLE  PPM                                49.3
   NOX BACKGRD METER READING/SCALE                 1.0/2
   NOX BACKGRD PPM                                 1.0
   HC  CONCENTRATION PPM                            62
   CO  CONCENTRATION PPM                            95
   CO2 CONCENTRATION PCT                          1.79
   NOX CONCENTRATION PPM                          48.4
   SO2 COCENTRATION PPM                            0.0
   HC  MASS (GRAMS)                               5.52
   CO  MASS (GRAMS)                              16.98
   CO2 MASS (GRAMS)                            5073.83
   NOX MASS (GRAMS)                              11.87
   SO2 MASS (GRAMS)                               0.00

HC  GRAMS/KILOMETRE       .25
CO  GRAMS/KILOMETRE       .78
CO2 GRAMS/KILOMETRE    233
NOX GRAMS/KILOMETRE       .55
SO2 GRAMS/KILOMETRE      0.00

HC  GRAMS/KG OF FUEL   3.38     HC  GRAMS/MIN        .2
CO  GRAMS/KG OF FUEL   10.4     CO  GRAMS/MIN       .7
CO2 GRAMS/KG OF FUEL   3110     CO2 GRAMS/MIN     218
NOX GRAMS/KG OF FUEL   7.28     NOX GRAMS/MIN     .51
SO2 GRAMS/KG OF FUEL   0.00     SO2 GRAMS/MIN    0.00

CARBON BALANCE FUEL CONSUMPTION =  8.91 LITRES PER HUNDRED KILOMETRES
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       TABLE  E-24   EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                                VEHICLE NUMBER

DATE 10/21/76                   TIME     -0 HRS.         TEST NO.  3
MODEL  1976 OLDS DIESEL CTLFET                           ENGINE 5.7 LITRE     8 CYL.
DRIVER   DT                     TEST WT.  2041 KG.       GVW     0 KG
WET BULB TEMP  18 C             DRY BULB TEMP  24 C      REL. HUM.  58.5 PCT
SPEC. HUM.  11.0 GRAM/KG        BARO.  746.8 MM  HG.     MEASURED FUEL  0.00 KG

  RUN DURATION            12.78 MINUTES
  BLOWER INLET PRESS. 254.1  MM. H2O
  BLOWER DIF.  PRESS. 312.4  MM  H2O
  BLOWER INLET TEMP.     51  DEG. C
  DYNO REVOLUTIONS     24068
  BLOWER REVOLUTIONS     11406
  BLOWER CU. CM /REV.  8382

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE             17.7/3
   HC   SAMPLE  PPM                               71
   HC   BACKGRD METER READING/SCALE              2.7/3
   HC   BACKGRD PPM                               11
   CO   SAMPLE  METER READING/SCALE             54.4/*
   CO   SAMPLE  PPM                              118
   CO   BACKGRD METER READING/SCALE               .8/*
   CO   BACKGRD PPM                                1
   CO2  SAMPLE  METER READING/SCALE             48.0/2
   CO2  SAMPLE  PERCENT                          2.17
   CO2  BACKGRD METER READING/SCALE              1.9/2
   CO2  BACKGRD PERCENT                          .07
   NOX  SAMPLE  METER READING/SCALE             65.2/2
   NOX  SAMPLE  PPM                             65.2
   NOX  BACKGRD METER READING/SCALE              1.1/2
   NOX  BACKGRD PPM                              1.1
   HC   CONCENTRATION PPM                         62
   CO   CONCENTRATION PPM                        110
   CO2  CONCENTRATION PCT                       2.11
   NOX  CONCENTRATION PPM                       64.3
   SO2  COCENTRATION PPM                         0.0
   HC   MASS (GRAMS)                            2.94
   CO   MASS (GRAMS)                           10.59
   CO2  MASS (GRAMS)                         3209.28
   NOX  MASS (GRAMS)                           10.26
   SO2  MASS (GRAMS)                            0.00

HC   GRAMS/KILOMETRE       .18
CO   GRAMS/KILOMETRE       .64
CO2  GRAMS/KILOMETRE   195
NOX  GRAMS/KILOMETRE       .62
SO2  GRAMS/KILOMETRE      0.00

HC   GRAMS/KG OF FUEL   2.86     HC   GRAMS/MIN        .2
CO   GRAMS/KG OF FUEL   10.3     CO   GRAMS/MIN      .8
CO2  GRAMS/KG OF FUEL   3112     CO2  GRAMS/MIN     251
NOX  GRAMS/KG OF FUEL   9.95     NOX  GRAMS/MIN     .80
SO2  GRAMS/KG OF FUEL   0.00     SO2  GRAMS/MIN    0.00

CARBON BALANCE FUEL CONSUMPTION =  7.43 LITRES PER HUNDRED KILOMETRES
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TABLE E-25. GASEOUS EMISSIONS SUMMARY - 1977 OLDSMOBILE CUTLASS (GASOLINE) (TRANSIENT CYCLES)

Cycle	Date	Test No.	Emission Rate, g/km			Fuel Cons. ℓ/100 km	Fuel Econ. mpg
			HC	CO	NO_x		
1975 FTP	12/29/76	1	0.27	1.27	0.82	14.87	15.82
	12/30/76	2	0.23	1.26	0.87	15.64	15.04
	1/3/77	3	0.22	1.48	0.85	14.81	15.89
	Average		0.24	1.34	0.85	15.11	15.58
			(0.39)	(2.16)	(1.37)		
FTP_c	12/29/76	1	0.41	2.41	1.02	15.73	14.96
	12/30/76	2	0.40	1.86	1.02	16.49	14.27
	1/3/77	3	0.37	2.79	1.02	15.55	15.13
	Average		0.39	2.35	1.02	15.92	14.79
			(0.63)	(3.78)	(1.64)		
FTP_h	12/29/76	1	0.18	0.31	0.61	13.85	16.99
	12/30/76	2	0.11	0.78	0.72	14.36	16.38
	1/3/77	3	0.14	0.55	0.72	14.59	16.13
	Average		0.14	0.55	0.68	14.27	16.50
			(0.22)	(0.88)	(1.09)		
SET	12/29/76	1	0.07	0.23	0.84	11.57	20.34
	12/30/76	2	0.07	0.59	0.87	11.96	19.67
	1/3/77	3	0.09	0.76	0.86	11.97	19.66
	Average		0.08	0.53	0.86	11.83	19.89
			(0.13)	(0.85)	(1.38)		
FET	12/29/76	1	0.05	0.10	0.84	9.92	23.72
	12/30/76	2	0.06	0.17	1.00	10.44	22.54
	1/3/77	3	0.06	0.09	0.79	10.38	22.67
			0.06	0.12	0.88	10.24	22.98
			(0.10)	(0.19)	(1.42)		

( ) Values in parentheses are in grams/mile

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                   TABLE  E-26            VEHICLE EMISSION RESULTS
                                    1975  LIGHT DUTY EMISSIONS TEST
                                                                    MFGR. CODE   -0                YR.  1977
UNIT NO.  415        TEST NO. 1  75 FTP   DATE 12/29/76              CURB WT.  1814 KG              GVM      0 KG
VEHICLE MODEL  OLDS GAS CUTLASS            ENGINE   4.26 LITRE 8

BAROMETER 742.19 MM OF HG.                                          WET BULB TEMP  15.6 DEG. C
DRY BULB TEMP.    25.0 DEG. C                                        ABS. HUMIDITY    7.2 GRAMS/KG
REL. HUMIDITY      36 PCT.

EXHAUST EMISSIONS                                                   BLOWER INLET PRESS., G1 594.4 MM. H2O
                                                                    BLOWER INLET TEMP.    42 DEG. C
     BLOWER DIF. PRESS., G2, 591.8 MM. H2O
     BAG RESULTS
     BAG NO.                                  1            2            3
     BLOWER REVOLUTIONS                    40886        69897        40798
     HC    SAMPLE  METER READING/SCALE      11.4/3       18.2/2       46.6/2
     HC    SAMPLE  PPM                      114          18           47
     HC    BACKGRD METER READING/SCALE      11.9/2       1.5/3        11.8/2
     HC    BACKGRD PPM                      12           15           12
     CO    SAMPLE  METER READING/SCALE      74.1/*       12.1/*       48.1/*
     CO    SAMPLE  PPM                      323          11           45
     CO    BACKGRD METER READING/SCALE      1.6/*        1.1/*        3.0/*
     CO    BACKGRD PPM                      5            3            3
     CO2   SAMPLE  METER READING/SCALE      83.2/3       55.3/3       70.7/3
     CO2   SAMPLE  PERCENT                  1.54         .97          1.28
     CO2   BACKGRD METER READING/SCALE      3.6/3        3.8/3        3.8/3
     CO2   BACKGRD PERCENT                  .06          .06          .06
     NOX   SAMPLE  METER READING/SCALE      71.0/2       12.9/2       40.4/2
     NOX   SAMPLE  PPM                      71.0         12.9         40.4
     NOX   BACKGRD METER READING/SCALE      .6/2         .6/2         .5/2
     NOX   BACKGRD PPM                      .6           .6           .5
     SO2   SAMPLE  METER READING/SCALE      -0.0/*       -0.0/*       -0.0/*
     SO2   SAMPLE  PPM                      -0.0         -0.0         -0.0
     SO2   BACKGRD METER READING/SCALE      -0.0/*       -0.0/*       -0.0/*
     SO2   BACKGRD PPM                      -0.0         -0.0         -0.0

     HC    CONCENTRATION PPM                104          4            36
     CO    CONCENTRATION PPM                306          8            41
     CO2   CONCENTRATION PCT                1.49         .92          1.23
     NOX   CONCENTRATION PPM                70.5         12.3         39.9
     SO2   CONCENTRATION PPM                0.0          0.0          0.0
     HC    MASS GRAMS                       4.67         .33          1.62
     CO    MASS GRAMS                       27.82        1.27         3.74
     CO2   MASS GRAMS                       2138.14      2251.24      1758.22
     NOX   MASS GRAMS                       9.45         2.83         5.35
     SO2   MASS GRAMS                       0.00         0.00         0.00

      WEIGHTED MASS HC        .27 GRAMS/KILOMETRE
      WEIGHTED MASS CO       1.27 GRAMS/KILOMETRE
      WEIGHTED MASS CO2    345.79 GRAMS/KILOMETRE
      WEIGHTED MASS NOX       .82 GRAMS/KILOMETRE
      WEIGHTED MASS SO2      0.00 GRAMS/KILOMETRE

     CARBON BALANCE FUEL CONSUMPTION = 14.87 LITRES PER HUNDRED KILOMETRES
     TOTAL CVS FLOW =    289.8 STD. CU. METRES
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                 TABLE  E-27           VEHICLE EMISSION RESULTS
                                   1975  LIGHT DUTY EMISSIONS TEST
UNIT NO.  415         TEST NO. 1   FTP Cold DATE 12/29/76             MFGR. CODE   -0                  YR.  1977
VEHICLE MODEL  OLDS GAS CUTLASS           ENGINE   4.26 LITRE 8       CURB WT.  1814 KG               GVM      0 KG

BAROMETER 742.19 MM OF HG.                                           WET BULB TEMP  15.6 DEG. C
DRY BULB TEMP.    25.0 DEG. C                                         ABS. HUMIDITY   7.2 GRAMS/KG
REL. HUMIDITY      36 PCT.

EXHAUST EMISSIONS
                                                                     BLOWER INLET PRESS., G1 594.4 MM. H2O
   BLOWER DIF. PRESS., G2, 591.8 MM. H2O                             BLOWER INLET TEMP.   42 DEG. C
   BAG RESULTS
   BAG NO.                                        1          2          3
   BLOWER REVOLUTIONS                           40886      69897      40886
   HC   SAMPLE  METER READING/SCALE            11.4/3     18.2/2     11.4/3
   HC   SAMPLE  PPM                             114         18        114
   HC   BACKGRD METER READING/SCALE            11.9/2      1.5/3     11.9/2
   HC   BACKGRD PPM                              12         15         12
   CO   SAMPLE  METER READING/SCALE            74.1/*     12.1/*     74.1/*
   CO   SAMPLE  PPM                             323         11        323
   CO   BACKGRD METER READING/SCALE             1.6/*      1.1/*      1.6/*
   CO   BACKGRD PPM                               5          3          5
   CO2  SAMPLE  METER READING/SCALE            83.2/3     55.3/3     83.2/3
   CO2  SAMPLE  PERCENT                        1.54        .97       1.54
   CO2  BACKGRD METER READING/SCALE             3.6/3      3.8/3      3.6/3
   CO2  BACKGRD PERCENT                         .06        .06        .06
   NOX  SAMPLE  METER READING/SCALE            71.0/2     12.9/2     71.0/2
   NOX  SAMPLE  PPM                            71.0       12.9       71.0
   NOX  BACKGRD METER READING/SCALE              .6/2       .6/2       .6/2
   NOX  BACKGRD PPM                              .6         .6         .6
   SO2  SAMPLE  METER READING/SCALE            -0.0/*     -0.0/*     -0.0/*
   SO2  SAMPLE  PPM                            -0.0       -0.0       -0.0
   SO2  BACKGRD METER READING/SCALE            -0.0/*     -0.0/*     -0.0/*
   SO2  BACKGRD PPM                            -0.0       -0.0       -0.0

   HC   CONCENTRATION PPM                       104          4        104
   CO   CONCENTRATION PPM                       306          8        306
   CO2  CONCENTRATION PCT                      1.49        .92       1.49
   NOX  CONCENTRATION PPM                      70.5       12.3       70.5
   SO2  CONCENTRATION PPM                       0.0        0.0        0.0
   HC   MASS GRAMS                             4.67        .33       4.67
   CO   MASS GRAMS                            27.82       1.27      27.82
   CO2  MASS GRAMS                          2138.14    2251.24    2138.14
   NOX  MASS GRAMS                             9.45       2.83       9.45
   SO2  MASS GRAMS                             0.00       0.00       0.00

   WEIGHTED MASS HC        .41 GRAMS/KILOMETRE
   WEIGHTED MASS CO       2.41 GRAMS/KILOMETRE
   WEIGHTED MASS CO2    363.74 GRAMS/KILOMETRE
   WEIGHTED MASS NOX      1.02 GRAMS/KILOMETRE
   WEIGHTED MASS SO2      0.00 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION = 15.73 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =    290.0 STD. CU. METRES
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                                TABLE  E-28              VEHICLE EMISSION RESULTS
                                                   1975  LIGHT DUTY EMISSIONS TEST
UNIT NO.  415          TEST NO. 1  FTP Hot  DATE 12/29/76                        MFGR. CODE   -0                     YR.  1977
VEHICLE MODEL  OLDS GAS CUTLASS             ENGINE   4.26 LITRE 8                CURB WT.  1814 KG                   GVM     0 KG

BAROMETER 742.19 MM OF HG.                                                      WET BULB TEMP  13.3 DEG. C
DRY BULB TEMP.    25.6 DEG. C                                                    ABS. HUMIDITY   4.5 GRAMS/KG
REL. HUMIDITY      22 PCT.

EXHAUST EMISSIONS
                                                                                BLOWER INLET PRESS., G1 609.6 MM. H2O
     BLOWER DIF. PRESS., G2, 607.1 MM. H2O                                      BLOWER INLET TEMP.   41 DEG. C
     BAG RESULTS
     BAG NO.                                        1               2               3
     BLOWER REVOLUTIONS                          40798           70004           40798
     HC    SAMPLE  METER READING/SCALE          46.6/2          16.8/2          46.6/2
     HC    SAMPLE  PPM                             47              17              47
     HC    BACKGRD METER READING/SCALE          11.8/2          10.8/2          11.8/2
     HC    BACKGRD PPM                             12              11              12
     CO    SAMPLE  METER READING/SCALE          48.1/*           1.4/*          48.1/*
     CO    SAMPLE  PPM                             45               1              45
     CO    BACKGRD METER READING/SCALE           3.0/*           1.3/*           3.0/*
     CO    BACKGRD PPM                              3               1               3
     CO2   SAMPLE  METER READING/SCALE          70.7/3          53.1/3          70.7/3
     CO2   SAMPLE  PERCENT                       1.28             .93            1.28
     CO2   BACKGRD METER READING/SCALE           3.8/3           3.7/3           3.8/3
     CO2   BACKGRD PERCENT                        .06             .06             .06
     NOX   SAMPLE  METER READING/SCALE          40.4/2          11.6/2          40.4/2
     NOX   SAMPLE  PPM                           40.4            11.6            40.4
     NOX   BACKGRD METER READING/SCALE            .5/2            .4/2            .5/2
     NOX   BACKGRD PPM                             .5              .4              .5
     SO2   SAMPLE  METER READING/SCALE          -0.0/*          -0.0/*          -0.0/*
     SO2   SAMPLE  PPM                           -0.0            -0.0            -0.0
     SO2   BACKGRD METER READING/SCALE          -0.0/*          -0.0/*          -0.0/*
     SO2   BACKGRD PPM                           -0.0            -0.0            -0.0

     HC    CONCENTRATION PPM                       36               7              36
     CO    CONCENTRATION PPM                       41               0              41
     CO2   CONCENTRATION PCT                     1.23             .87            1.23
     NOX   CONCENTRATION PPM                     39.9            11.2            39.9
     SO2   CONCENTRATION PPM                      0.0             0.0             0.0
     HC    MASS GRAMS                            1.61             .52            1.61
     CO    MASS GRAMS                            3.75             .02            3.75
     CO2   MASS GRAMS                         1756.06         2149.37         1756.06
     NOX   MASS GRAMS                            4.95            2.39            4.95
     SO2   MASS GRAMS                            0.00            0.00            0.00

     WEIGHTED MASS HC        .18 GRAMS/KILOMETRE
     WEIGHTED MASS CO        .31 GRAMS/KILOMETRE
     WEIGHTED MASS CO2    323.63 GRAMS/KILOMETRE
     WEIGHTED MASS NOX       .61 GRAMS/KILOMETRE
     WEIGHTED MASS SO2      0.00 GRAMS/KILOMETRE

    CARBON BALANCE FUEL CONSUMPTION = 13.85 LITRES PER HUNDRED KILOMETRES
    TOTAL CVS FLOW =    289.5 STD. CU. METRES
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          TABLE  E-29   EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                               VEHICLE NUMBER 415

   DATE 12/29/76                  TIME     -0 HRS.         TEST NO. 1
   MODEL  1977 OLDS GAS CUTLASSEI-7                        ENGINE 4.3 LITRE  8
   DRIVER   DT                    TEST WT.  2041 KG.       GVW    0 KG
   WET BULB TEMP  14 C            DRY BULB TEMP  27 C      REL. HUM.  23.8 PCT
   SPEC. HUM.    5.3 GRAM/KG      BARO.  742.2 MM  HG.     MEASURED FUEL  0.00 KG

     RUN DURATION          23.26 MINUTES
     BLOWER INLET PRESS. 607.1  MM. H2O
     BLOWER DIF.  PRESS. 607.1  MM  H2O
     BLOWER INLET TEMP.     40  DEG. C
     DYNO REVOLUTIONS     31115
     BLOWER REVOLUTIONS   112490
     BLOWER CU. CM /REV.  2230

     BAG RESULTS
      HC   SAMPLE  METER READING/SCALE              22.3/2
      HC   SAMPLE  PPM                                22
      HC   BACKGRD METER READING/SCALE              10.4/2
      HC   BACKGRD PPM                                10
      CO   SAMPLE  METER READING/SCALE              23.2/*
      CO   SAMPLE  PPM                                22
      CO   BACKGRD METER READING/SCALE               1.5/*
      CO   BACKGRD PPM                                 1
      CO2 SAMPLE   METER READING/SCALE              82.9/3
      CO2 SAMPLE   PERCENT                          1.53
      CO2 BACKGRD METER READING/SCALE                3.6/3
      CO2 BACKGRD PERCENT                             .06
      NOX SAMPLE   METER READING/SCALE              53.0/2
      NOX SAMPLE   PPM                              53.0
      NOX BACKGRD METER READING/SCALE                 .6/2
      NOX BACKGRD PPM                                  .6
      HC   CONCENTRATION PPM                          13
      CO   CONCENTRATION PPM                          20
      CO2 CONCENTRATION PCT                         1.48
      NOX CONCENTRATION PPM                         52.5
      SO2 COCENTRATION PPM                           0.0
      HC   MASS (GRAMS)                             1.63
      CO   MASS (GRAMS)                             4.92
      CO2 MASS (GRAMS)                           5870.31
      NOX MASS (GRAMS)                             18.35
      SO2 MASS (GRAMS)                              0.00

   HC   GRAMS/KILOMETRE       .07
   CO   GRAMS/KILOMETRE       .23
   CO2 GRAMS/KILOMETRE     270
   NOX GRAMS/KILOMETRE        .84
   SO2 GRAMS/KILOMETRE       0.00

   HC   GRAMS/KG OF FUEL     .88      HC   GRAMS/MIN      .07
   CO   GRAMS/KG OF FUEL     2.6      CO   GRAMS/MIN       .2
   CO2 GRAMS/KG OF FUEL     3162      CO2 GRAMS/MIN      252
   NOX GRAMS/KG OF FUEL     9.88      NOX GRAMS/MIN      .79
   SO2 GRAMS/KG OF FUEL     0.00      SO2 GRAMS/MIN     0.00
   CARBON BALANCE FUEL ECONOMY =    11.57 LITRES PER HUNDRED KILOMETERS
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        TABLE E-30    EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                             VEHICLE NUMBER 415

DATE 12/29/76                 TIME    -0 HRS.         TEST NO. 1
MODEL  1977 OLDS GAS CUTLASFET                        ENGINE 4.3 LITRE  8
DRIVER   DT                   TEST WT.  2041 KG.      GVW    0 KG
WET BULB TEMP  14 C           DRY BULB TEMP  26 C     REL. HUM.  25.7 PCT
SPEC. HUM.   5.5 GRAM/KG      BARO.  742.2 MM  HG.    MEASURED FUEL  0.00 KG

  RUN DURATION            12.77 MINUTES
  BLOWER INLET PRESS. 604.5  MM. H2O
  BLOWER DIF.  PRESS. 604.5  MM  H2O
  BLOWER INLET TEMP.     41  DEG. C
  DYNO REVOLUTIONS     23797
  BLOWER REVOLUTIONS    61699
  BLOWER CU. CM /REV.  2233

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE            20.4/2
   HC   SAMPLE  PPM                             20
   HC   BACKGRD METER READING/SCALE            10.8/2
   HC   BACKGRD PPM                             11
   CO   SAMPLE  METER READING/SCALE            14.6/*
   CO   SAMPLE  PPM                             14
   CO   BACKGRD METER READING/SCALE             1.3/*
   CO   BACKGRD PPM                              1
   CO2  SAMPLE  METER READING/SCALE            41.4/2
   CO2  SAMPLE  PERCENT                        1.81
   CO2  BACKGRD METER READING/SCALE             3.9/3
   CO2  BACKGRD PERCENT                         .06
   NOX  SAMPLE  METER READING/SCALE            72.2/2
   NOX  SAMPLE  PPM                            72.2
   NOX  BACKGRD METER READING/SCALE              .6/2
   NOX  BACKGRD PPM                              .6
   HC   CONCENTRATION PPM                       11
   CO   CONCENTRATION PPM                       12
   CO2  CONCENTRATION PCT                      1.76
   NOX  CONCENTRATION PPM                      71.7
   SO2  COCENTRATION PPM                        0.0
   HC   MASS (GRAMS)                            .75
   CO   MASS (GRAMS)                           1.66
   CO2  MASS (GRAMS)                         3821.60
   NOX  MASS (GRAMS)                          13.81
   SO2  MASS (GRAMS)                           0.00

 HC   GRAMS/KILOMETRE      .05
 CO   GRAMS/KILOMETRE      .10
 CO2  GRAMS/KILOMETRE    232
 NOX  GRAMS/KILOMETRE      .84
 SO2  GRAMS/KILOMETRE     0.00

 HC   GRAMS/KG OF FUEL     .62     HC   GRAMS/MIN     .06
 CO   GRAMS/KG OF FUEL     1.4     CO   GRAMS/MIN      .1
 CO2  GRAMS/KG OF FUEL    3165     CO2  GRAMS/MIN     249
 NOX  GRAMS/KG OF FUEL   11.44     NOX  GRAMS/MIN    1.08
 SO2  GRAMS/KG OF FUEL    0.00     SO2  GRAMS/MIN    0.00
 CARBON BALANCE FUEL ECONOMY =    9.92 LITRES PER HUNDRED KILOMETERS
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                         TABLE  E-31               VEHICLE EMISSION RESULTS
                                               1975  LIGHT DUTY EMISSIONS TEST
UNIT NO.  415          TEST NO. 2  75 FTP    DATE 12/30/76                        MFGR. CODE   -0              YR.  1977
VEHICLE MODEL   OLDS GAS CUTLASS             ENGINE    4.26 LITRE 8               CURB WT.  1814 KG            GVM      0 KG

BAROMETER 736.60 MM OF HG.                                                   WET BULB TEMP  16.1 DEG. C
DRY BULB TEMP.    24.4 DEG. C                                                 ABS. HUMIDITY   8.2 GRAMS/KG
REL. HUMIDITY      42 PCT.

EXHAUST EMISSIONS
                                                                             BLOWER INLET PRESS., G1 647.7 MM. H2O
    BLOWER DIF. PRESS., G2, 647.7 MM. H2O                                    BLOWER INLET TEMP.   42 DEG. C
    BAG RESULTS
    BAG NO.                                       1              2              3
    BLOWER REVOLUTIONS                          40710          69809          40582
    HC    SAMPLE  METER READING/SCALE            12.0/3         23.1/2         36.4/2
    HC    SAMPLE  PPM                            120            23             36
    HC    BACKGRD METER READING/SCALE            2.1/3          2.0/3          16.4/2
    HC    BACKGRD PPM                            21             20             16
    CO    SAMPLE  METER READING/SCALE            64.1/*         2.2/*          51.7/*
    CO    SAMPLE  PPM                            262            2              112
    CO    BACKGRD METER READING/SCALE            .4/*           .2/*           .7/*
    CO    BACKGRD PPM                            1              1              1
    CO2   SAMPLE  METER READING/SCALE            88.6/3         58.5/3         75.6/3
    CO2   SAMPLE  PERCENT                        1.65           1.03           1.38
    CO2   BACKGRD METER READING/SCALE            3.5/3          3.9/3          3.8/3
    CO2   BACKGRD PERCENT                        .05            .06            .06
    NOX   SAMPLE  METER READING/SCALE            69.1/2         14.0/2         44.8/2
    NOX   SAMPLE  PPM                            69.1           14.0           44.8
    NOX   BACKGRD METER READING/SCALE            .8/2           .7/2           .7/2
    NOX   BACKGRD PPM                            .8             .7             .7
    SO2   SAMPLE  METER READING/SCALE            -0.0/*         -0.0/*         -0.0/*
    SO2   SAMPLE  PPM                            -0.0           -0.0           -0.0
    SO2   BACKGRD METER READING/SCALE            -0.0/*         -0.0/*         -0.0/*
    SO2   BACKGRD PPM                            -0.0           -0.0           -0.0

    HC    CONCENTRATION PPM                      102            5              22
    CO    CONCENTRATION PPM                      249            2              106
    CO2   CONCENTRATION PCT                      1.60           .98            1.33
    NOX   CONCENTRATION PPM                      68.4           13.4           44.2
    SO2   CONCENTRATION PPM                      0.0            0.0            0.0
    HC    MASS GRAMS                             4.49           .35            .96
    CO    MASS GRAMS                             22.24          .23            9.44
    CO2   MASS GRAMS                             2255.83        2361.56        1862.13
    NOX   MASS GRAMS                             9.25           3.10           5.96
    SO2   MASS GRAMS                             0.00           0.00           0.00

    WEIGHTED MASS HC        .23 GRAMS/KILOMETRE
    WEIGHTED MASS CO       1.26 GRAMS/KILOMETRE
    WEIGHTED MASS CO2    364.03 GRAMS/KILOMETRE
    WEIGHTED MASS NOX       .87 GRAMS/KILOMETRE
    WEIGHTED MASS SO2      0.00 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION = 15.64 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =    284.3 STD. CU. METRES
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                  TABLE  E-32              VEHICLE EMISSION RESULTS
                                      1975  LIGHT DUTY EMISSIONS TEST
                                                                 MFGR. CODE   -0            YR.  1977
UNIT NO.  415        TEST NO. 2 FTP Cold   DATE 12/30/76        CURB WT.  1814 KG           GVM     0 KG
VEHICLE MODEL  OLDS GAS CUTLASS            ENGINE   4.26 LITRE 8

                                                            WET BULB TEMP  16.1 DEG. C
BAROMETER 736.60 MM OF HG.                                   ABS. HUMIDITY   8.2 GRAMS/KG
DRY BULB TEMP.    24.4 DEG. C
REL. HUMIDITY      42 PCT.

EXHAUST EMISSIONS                                           BLOWER INLET PRESS., G1 647.7 MM. H2O
                                                            BLOWER INLET TEMP.   42 DEG. C
    BLOWER DIF. PRESS., G2, 647.7 MM. H2O
    BAG RESULTS
    BAG NO.                                     1             2             3
    BLOWER REVOLUTIONS                      40710         69809         40710
    HC   SAMPLE  METER READING/SCALE        12.0/3        23.1/2        12.0/3
    HC   SAMPLE  PPM                          120            23           120
    HC   BACKGRD METER READING/SCALE        2.1/3         2.0/3         2.1/3
    HC   BACKGRD PPM                           21            20            21
    CO   SAMPLE  METER READING/SCALE       64.1/*         2.2/*        64.1/*
    CO   SAMPLE  PPM                          262             2           262
    CO   BACKGRD METER READING/SCALE         .4/*          .2/*          .4/*
    CO   BACKGRD PPM                            1             1             1
    CO2  SAMPLE  METER READING/SCALE       88.6/3        58.5/3        88.6/3
    CO2  SAMPLE  PERCENT                     1.65          1.03          1.65
    CO2  BACKGRD METER READING/SCALE        3.5/3         3.9/3         3.5/3
    CO2  BACKGRD PERCENT                      .05           .06           .05
    NOX  SAMPLE  METER READING/SCALE       69.1/2        14.0/2        69.1/2
    NOX  SAMPLE  PPM                         69.1          14.0          69.1
    NOX  BACKGRD METER READING/SCALE         .8/2          .7/2          .8/2
    NOX  BACKGRD PPM                           .8            .7            .8
    SO2  SAMPLE  METER READING/SCALE      -0.0/*        -0.0/*        -0.0/*
    SO2  SAMPLE  PPM                         -0.0          -0.0          -0.0
    SO2  BACKGRD METER READING/SCALE      -0.0/*        -0.0/*        -0.0/*
    SO2  BACKGRD PPM                         -0.0          -0.0          -0.0

    HC   CONCENTRATION PPM                    102             5           102
    CO   CONCENTRATION PPM                    249             2           249
    CO2  CONCENTRATION PCT                   1.60           .98          1.60
    NOX  CONCENTRATION PPM                   68.4          13.4          68.4
    SO2  CONCENTRATION PPM                    0.0           0.0           0.0
    HC   MASS GRAMS                          4.49           .35          4.49
    CO   MASS GRAMS                         22.24           .23         22.24
    CO2  MASS GRAMS                       2255.83       2361.56       2255.83
    NOX  MASS GRAMS                          9.25          3.10          9.25
    SO2  MASS GRAMS                          0.00          0.00          0.00

    WEIGHTED MASS HC       .40 GRAMS/KILOMETRE
    WEIGHTED MASS CO      1.86 GRAMS/KILOMETRE
    WEIGHTED MASS CO2   382.63 GRAMS/KILOMETRE
    WEIGHTED MASS NOX     1.02 GRAMS/KILOMETRE
    WEIGHTED MASS SO2     0.00 GRAMS/KILOMETRE

   CARBON BALANCE FUEL CONSUMPTION = 16.49 LITRES PER HUNDRED KILOMETRES
   TOTAL CVS FLOW =   284.5 STD. CU. METRES
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          TABLE  E-33              VEHICLE EMISSION RESULTS
                                1975  LIGHT DUTY EMISSIONS TEST
UNIT NO.  415         TEST NO. 2 FTP HOT    DATE 12/30/76                MFGR. CODE   -0                  YR.  1977
VEHICLE MODEL  OLDS GAS CUTLASS             ENGINE   4.26 LITRE 8        CURB WT.  1814 KG                GVM      0 KG

BAROMETER 736.60 MM OF HG.                                              WET BULB TEMP  16.7 DEG. C
DRY BULB TEMP.    26.0 DEG. C                                            ABS. HUMIDITY   8.6 GRAMS/KG
REL. HUMIDITY      42 PCT.

EXHAUST EMISSIONS                                                       BLOWER INLET PRESS., G1 680.7 MM. H2O
                                                                        BLOWER INLET TEMP.   41 DEG. C
     BLOWER DIF. PRESS., G2, 680.7 MM. H2O
     BAG RESULTS
     BAG NO.                                        1               2                3
     BLOWER REVOLUTIONS                          40582           66645            40582
     HC   SAMPLE  METER READING/SCALE             36.4/2          19.5/2           36.4/2
     HC   SAMPLE  PPM                             36              19               36
     HC   BACKGRD METER READING/SCALE             16.4/2          15.0/2           16.4/2
     HC   BACKGRD PPM                             16              15               16
     CO   SAMPLE  METER READING/SCALE             51.7/*           1.2/*           51.7/*
     CO   SAMPLE  PPM                            112               1              112
     CO   BACKGRD METER READING/SCALE               .7/*            .7/*             .7/*
     CO   BACKGRD PPM                              1               1                1
     CO2  SAMPLE  METER READING/SCALE             75.6/3          57.4/3           75.6/3
     CO2  SAMPLE  PERCENT                         1.38            1.01             1.38
     CO2  BACKGRD METER READING/SCALE              3.8/3           3.9/3            3.8/3
     CO2  BACKGRD PERCENT                          .06             .06              .06
     NOX  SAMPLE  METER READING/SCALE             44.8/2          12.8/2           44.8/2
     NOX  SAMPLE  PPM                             44.8            12.8             44.8
     NOX  BACKGRD METER READING/SCALE               .7/2            .6/2             .7/2
     NOX  BACKGRD PPM                               .7              .6               .7
     SO2  SAMPLE  METER READING/SCALE            -0.0/*          -0.0/*           -0.0/*
     SO2  SAMPLE  PPM                            -0.0            -0.0             -0.0
     SO2  BACKGRD METER READING/SCALE            -0.0/*          -0.0/*           -0.0/*
     SO2  BACKGRD PPM                            -0.0            -0.0             -0.0

     HC   CONCENTRATION PPM                       22               6               22
     CO   CONCENTRATION PPM                      106               0              106
     CO2  CONCENTRATION PCT                      1.33             .96             1.33
     NOX  CONCENTRATION PPM                      44.2            12.2             44.2
     SO2  CONCENTRATION PPM                      0.0             0.0              0.0
     HC   MASS GRAMS                             .95             .40              .95
     CO   MASS GRAMS                            9.40             .00             9.40
     CO2  MASS GRAMS                         1854.98         2190.36          1854.98
     NOX  MASS GRAMS                            6.01            2.73             6.01
     SO2  MASS GRAMS                            0.00            0.00             0.00

     WEIGHTED MASS HC        .11 GRAMS/KILOMETRE
     WEIGHTED MASS CO        .78 GRAMS/KILOMETRE
     WEIGHTED MASS CO2    335.23 GRAMS/KILOMETRE
     WEIGHTED MASS NOX       .72 GRAMS/KILOMETRE
     WEIGHTED MASS SO2      0.00 GRAMS/KILOMETRE

   CARBON BALANCE FUEL CONSUMPTION = 14.36 LITRES PER HUNDRED KILOMETRES
   TOTAL CVS FLOW =   276.7 STD. CU. METRES
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     TABLE  [illegible]  EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                          VEHICLE NUMBER 915

DATE 12/30/76                 TIME    -0 HRS.        TEST NO. 2
MODEL  1977 OLDS GAS CUTLASSE1-7                     ENGINE 4.3 LITRE  8
DRIVER   DT                   TEST WT.  2041 KG.     GVW    0 KG
WET BULB TEMP  17 C           DRY BULB TEMP  26 C    REL. HUM.  40.0 PCT
SPEC. HUM.   8.9 GRAM/KG      BARO.  736.9 MM  HG.   MEASURED FUEL  0.00 KG

  RUN DURATION           23.29 MINUTES
  BLOWER INLET PRESS. 685.8  MM. H2O
  BLOWER DIF.  PRESS. 680.7  MM  H2O
  BLOWER INLET TEMP.      41  DEG. C
  DYNO REVOLUTIONS     31295
  BLOWER REVOLUTIONS    112300
  BLOWER CU. CM /REV.   2227

  BAG RESULTS
   HC   SAMPLE   METER READING/SCALE                25.5/2
   HC   SAMPLE   PPM                                  25
   HC   BACKGRD METER READING/SCALE                 13.8/2
   HC   BACKGRD PPM                                   14
   CO   SAMPLE   METER READING/SCALE                58.6/4
   CO   SAMPLE   PPM                                  56
   CO   BACKGRD METER READING/SCALE                  1.2/4
   CO   BACKGRD PPM                                    1
   CO2 SAMPLE   METER READING/SCALE                 87.0/3
   CO2 SAMPLE   PERCENT                             1.62
   CO2 BACKGRD METER READING/SCALE                   3.7/3
   CO2 BACKGRD PERCENT                               .06
   NOX SAMPLE   METER READING/SCALE                 51.0/2
   NOX SAMPLE   PPM                                 51.0
   NOX BACKGRD METER READING/SCALE                   .7/2
   NOX BACKGRD PPM                                    .7
   HC   CONCENTRATION PPM                             13
   CO   CONCENTRATION PPM                             53
   CO2 CONCENTRATION PCT                            1.57
   NOX CONCENTRATION PPM                            50.4
   SO2 COCENTRATION PPM                              0.0
   HC   MASS (GRAMS)                                1.62
   CO   MASS (GRAMS)                               12.88
   CO2 MASS (GRAMS)                              6056.69
   NOX MASS (GRAMS)                                18.83
   SO2 MASS (GRAMS)                                 0.00

 HC   GRAMS/KILOMETRE       .07
 CO   GRAMS/KILOMETRE       .59
 CO2 GRAMS/KILOMETRE    279
 NOX GRAMS/KILOMETRE       .87
 SO2 GRAMS/KILOMETRE      0.00

 HC   GRAMS/KG OF FUEL    .85     HC   GRAMS/MIN     .07
 CO   GRAMS/KG OF FUEL    6.7     CO   GRAMS/MIN      .6
 CO2 GRAMS/KG OF FUEL   3156     CO2 GRAMS/MIN     260
 NOX GRAMS/KG OF FUEL   9.81     NOX GRAMS/MIN     .81
 SO2 GRAMS/KG OF FUEL   0.00     SO2 GRAMS/MIN    0.00
 CARBON BALANCE FUEL ECONOMY =   11.96 LITRES PER HUNDRED KILOMETERS
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        TABLE B-35   EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                           VEHICLE NUMBER 415

DATE 12/30/76               TIME    40 HRS.         TEST NO. 2
MODEL  1977 OLDS GAS CUTLASFET                      ENGINE 4.3 LITRE  8
DRIVER  DT                  TEST WT.  2041 KG.      GVW    0 KG
WET BULB TEMP  17 C         DRY BULB TEMP  26 C     REL. HUM.  43.2 PCT
SPEC. HUM.   9.1 GRAM/KG    BARO.  736.9 MM  HG.    MEASURED FUEL  0.00 KG

  RUN DURATION          12.76 MINUTES
  BLOWER INLET PRESS. 680.7  MM. H2O
  BLOWER DIF.  PRESS. 680.7  MM  H2O
  BLOWER INLET TEMP.      42  DEG. C
  DYNO REVOLUTIONS    23967
  BLOWER REVOLUTIONS     61634
  BLOWER CU. CM./REV.  2231

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE               27.0/2
   HC   SAMPLE  PPM                                  27
   HC   BACKGRD METER READING/SCALE               13.2/2
   HC   BACKGRD PPM                                  13
   CO   SAMPLE  METER READING/SCALE               25.1/4
   CO   SAMPLE  PPM                                  23
   CO   BACKGRD METER READING/SCALE                1.3/4
   CO   BACKGRD PPM                                   1
   CO2 SAMPLE  METER READING/SCALE                43.8/2
   CO2 SAMPLE  PERCENT                            1.94
   CO2 BACKGRD METER READING/SCALE                 1.5/2
   CO2 BACKGRD PERCENT                             .05
   NOX SAMPLE  METER READING/SCALE                79.6/2
   NOX SAMPLE  PPM                                79.6
   NOX BACKGRD METER READING/SCALE                  .8/2
   NOX BACKGRD PPM                                  .8
   HC   CONCENTRATION PPM                           16
   CO   CONCENTRATION PPM                           21
   CO2 CONCENTRATION PCT                          1.89
   NOX CONCENTRATION PPM                          78.9
   SO2 CNCENTRATION PPM                           0.0
   HC   MASS (GRAMS)                              1.05
   CO   MASS (GRAMS)                              2.84
   CO2 MASS (GRAMS)                            4015.83
   NOX MASS (GRAMS)                              16.51
   SO2 MASS (GRAMS)                               0.00

HC   GRAMS/KILOMETRE        .06
CO   GRAMS/KILOMETRE        .17
CO2 GRAMS/KILOMETRE     244
NOX GRAMS/KILOMETRE       1.00
SO2 GRAMS/KILOMETRE       0.00

HC   GRAMS/KG OF FUEL     .82      HC   GRAMS/MIN     .08
CO   GRAMS/KG OF FUEL     2.2      CO   GRAMS/MIN      .2
CO2 GRAMS/KG OF FUEL    3163      CO2 GRAMS/MIN     315
NOX GRAMS/KG OF FUEL   13.00      NOX GRAMS/MIN    1.29
SO2 GRAMS/KG OF FUEL    0.00      SO2 GRAMS/MIN    0.00
CARBON BALANCE FUEL ECONOMY =   10.44 LITRES PER HUNDRED KILOMETERS
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                        TABLE [illegible]            VEHICLE EMISSION RESULTS
                                                1975  LIGHT DUTY EMISSIONS TEST
VEH. NO.              TEST NO. 3  75 FTP  DATE  1/ 3/77                   MFGR. CODE   -0                    YR.  1977
   VEH. MODEL  OLDS GAS CUTLASS           ENGINE   4.26 LITRE 8           CURB WT.  1814 KG                  GVM      0 KG
BAROM.
DRY BULB 742.95 MM OF HG.                                               WET BULB TEMP  12.8 DEG. C
REL. HUM.TEMP.   22.2 DEG. C                                             ABS. HUMIDITY   5.4 GRAMS/KG
          ITY      38 PCT.
EXHAUST EMIS.
          [illegible]                                                   BLOWER INLET PRESS.  G1 [illegible] MM. H2O
    BLOWER DIF. PRESS., G2, 647.7 MM. H2O                              BLOWER INLET TEMP.   40 DEG. C
    BAG RESULTS
    BAG NO.                                      1              2              3
    BLOWER REVOLUTIONS                         40827          67731          40617
    HC    SAMPLE  METER READING/SCALE          10.3/3         16.3/2         34.4/2
    HC    SAMPLE  PPM                          103            16             34
    HC    BACKGRD METER READING/SCALE          10.8/2         1.4/3          10.4/2
    HC    BACKGRD PPM                          11             14             10
    CO    SAMPLE  METER READING/SCALE          83.0/*         4.2/*          68.0/*
    CO    SAMPLE  PPM                          386            4              66
    CO    BACKGRD METER READING/SCALE           .7/*           .8/*          1.4/*
    CO    BACKGRD PPM                           2              2              1
    CO2   SAMPLE  METER READING/SCALE          84.5/3         54.9/3         74.1/3
    CO2   SAMPLE  PERCENT                      1.56            .96           1.35
    CO2   BACKGRD METER READING/SCALE          3.4/3          3.4/3          3.2/3
    CO2   BACKGRD PERCENT                      .05            .05            .05
    NOX   SAMPLE  METER READING/SCALE          75.0/2         14.0/2         47.3/2
    NOX   SAMPLE  PPM                          75.0           14.0           47.3
    NOX   BACKGRD METER READING/SCALE           .4/2           .5/2           .5/2
    NOX   BACKGRD PPM                           .4             .5             .5
    SO2   SAMPLE  METER READING/SCALE          -0.0/*         -0.0/*         -0.0/*
    SO2   SAMPLE  PPM                          -0.0           -0.0           -0.0
    SO2   BACKGRD METER READING/SCALE          -0.0/*         -0.0/*         -0.0/*
    SO2   BACKGRD PPM                          -0.0           -0.0           -0.0

    HC    CONCENTRATION PPM                     93              3             25
    CO    CONCENTRATION PPM                    368              2             62
    CO2   CONCENTRATION PCT                    1.52            .91           1.30
    NOX   CONCENTRATION PPM                    74.6           13.5           46.9
    SO2   CONCENTRATION PPM                     0.0            0.0            0.0
    HC    MASS GRAMS                           4.19            .25           1.12
    CO    MASS GRAMS                          33.35            .27           5.62
    CO2   MASS GRAMS                        2169.95        2165.09        1854.93
    NOX   MASS GRAMS                           4.99           2.84           5.90
    SO2   MASS GRAMS                           0.00           0.00           0.00

    WEIGHTED MASS HC          .22 GRAMS/KILOMETRE
    WEIGHTED MASS CO         1.48 GRAMS/KILOMETRE
    WEIGHTED MASS CO2      344.35 GRAMS/KILOMETRE
    WEIGHTED MASS NOX         .85 GRAMS/KILOMETRE
    WEIGHTED MASS SO2        0.00 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION = 14.41 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =   284.0 STD. CU. METRES
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                 TABLE  E-37           VEHICLE EMISSION RESULTS
                                    1975  LIGHT DUTY EMISSIONS TEST
UNIT NO.             TEST NO. 1   FTP Cold DATE  1/ 3/77                 MFGR. CODE   -0                 YR.  1977
VEHICLE MODEL  OLDS GAS CUTLASS           ENGINE    4.26 LITRE 8          CURB WT.  1814 KG                GVM      0 KG

BAROMETER 742.95 MM OF HG.                                                WET BULB TEMP  12.8 DEG. C
DRY BULB TEMP.    22.2 DEG. C                                              ABS. HUMIDITY   5.4 GRAMS/KG
REL. HUMIDITY       32 PCT.

EXHAUST EMISSIONS
                                                                          BLOWER INLET PRESS., G1 647.7 MM. H2O
    BLOWER DIF. PRESS., G2, 647.7 MM. H2O                                  BLOWER INLET TEMP.   40 DEG. C
    BAG RESULTS
    BAG NO.                                      1              2              3
    BLOWER REVOLUTIONS                        40827          67731          40827
    HC    SAMPLE  METER READING/SCALE         10.3/3         16.3/2         10.3/3
    HC    SAMPLE  PPM                          103             16            103
    HC    BACKGRD METER READING/SCALE         10.8/2          1.4/3         10.8/2
    HC    BACKGRD PPM                           11             14             11
    CO    SAMPLE  METER READING/SCALE         83.0/*          4.2/*         83.0/*
    CO    SAMPLE  PPM                          386              4            386
    CO    BACKGRD METER READING/SCALE           .7/*           .8/*           .7/*
    CO    BACKGRD PPM                            2              2              2
    CO2   SAMPLE  METER READING/SCALE         84.5/3         54.9/3         84.5/3
    CO2   SAMPLE  PERCENT                     1.56            .96           1.56
    CO2   BACKGRD METER READING/SCALE          3.4/3          3.4/3          3.4/3
    CO2   BACKGRD PERCENT                      .05            .05            .05
    NOX   SAMPLE  METER READING/SCALE         75.0/2         14.0/2         75.0/2
    NOX   SAMPLE  PPM                         75.0           14.0           75.0
    NOX   BACKGRD METER READING/SCALE           .4/2           .5/2           .4/2
    NOX   BACKGRD PPM                           .4             .5             .4
    SO2   SAMPLE  METER READING/SCALE         -0.0/*         -0.0/*         -0.0/*
    SO2   SAMPLE  PPM                         -0.0           -0.0           -0.0
    SO2   BACKGRD METER READING/SCALE         -0.0/*         -0.0/*         -0.0/*
    SO2   BACKGRD PPM                         -0.0           -0.0           -0.0

    HC    CONCENTRATION PPM                     93              3             93
    CO    CONCENTRATION PPM                    368              2            368
    CO2   CONCENTRATION PCT                   1.52            .91           1.52
    NOX   CONCENTRATION PPM                   74.6           13.5           74.6
    SO2   CONCENTRATION PPM                    0.0            0.0            0.0
    HC    MASS GRAMS                          4.19            .25           4.19
    CO    MASS GRAMS                         33.35            .27          33.35
    CO2   MASS GRAMS                       2169.95        2165.02        2169.95
    NOX   MASS GRAMS                          9.44           2.84           9.44
    SO2   MASS GRAMS                          0.00           0.00           0.00

    WEIGHTED MASS HC        .37 GRAMS/KILOMETRE
    WEIGHTED MASS CO       2.79 GRAMS/KILOMETRE
    WEIGHTED MASS CO2    359.23 GRAMS/KILOMETRE
    WEIGHTED MASS NOX      1.02 GRAMS/KILOMETRE
    WEIGHTED MASS SO2      0.00 GRAMS/KILOMETRE

   CARBON BALANCE FUEL CONSUMPTION = 15.55 LITRES PER HUNDRED KILOMETRES
   TOTAL CVS FLOW =   284.4 STD. CU. METRES
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                      TABLE  B-30              VEHICLE EMISSION RESULTS
                                         1975  LIGHT DUTY EMISSIONS TEST
UNIT NO.              TEST NO. 1  FTP HOT  DATE  1/ 3/77                     MFGR. CODE   -0                    YR.  1977
VEHICLE MODEL  OLDS GAS CUTLASS            ENGINE   4.26 LITRE 8             CURB WT.  1814 KG                  GVM     0 KG

BAROMETER 742.45 MM OF HG.                                                 WET BULB TEMP  13.3 DEG. C
DRY BULB TEMP.    23.3 DEG. C                                               ABS. HUMIDITY    5.5 GRAMS/KG
REL. HUMIDITY      30 PCT.

EXHAUST EMISSIONS                                                          BLOWER INLET PRESS., G1 647.7 MM. H2O
                                                                           BLOWER INLET TEMP.    37 DEG. C
     BLOWER DIF. PRESS., G2, 647.7 MM. H2O
     BAG RESULTS
     BAG NO.                                      1                2                3
     BLOWER REVOLUTIONS                        40617            69659            40617
     HC   SAMPLE  METER READING/SCALE          34.4/2           16.6/2           34.4/2
     HC   SAMPLE  PPM                             34               17               34
     HC   BACKGRD METER READING/SCALE          10.4/2           10.1/2           10.4/2
     HC   BACKGRD PPM                             10               10               10
     CO   SAMPLE  METER READING/SCALE          68.0/*            8.2/*           68.0/*
     CO   SAMPLE  PPM                             66                8               66
     CO   BACKGRD METER READING/SCALE           1.4/*            1.8/*            1.4/*
     CO   BACKGRD PPM                              1                2                1
     CO2  SAMPLE  METER READING/SCALE          74.1/3           54.8/3           74.1/3
     CO2  SAMPLE  PERCENT                       1.35              .96             1.35
     CO2  BACKGRD METER READING/SCALE           3.2/3            3.1/3            3.2/3
     CO2  BACKGRD PERCENT                        .05              .05              .05
     NOX  SAMPLE  METER READING/SCALE          47.3/2           13.3/2           47.3/2
     NOX  SAMPLE  PPM                           47.3             13.3             47.3
     NOX  BACKGRD METER READING/SCALE            .5/2             .5/2             .5/2
     NOX  BACKGRD PPM                             .5               .5               .5
     SO2  SAMPLE  METER READING/SCALE          -0.0/*           -0.0/*           -0.0/*
     SO2  SAMPLE  PPM                           -0.0             -0.0             -0.0
     SO2  BACKGRD METER READING/SCALE          -0.0/*           -0.0/*           -0.0/*
     SO2  BACKGRD PPM                           -0.0             -0.0             -0.0

     HC   CONCENTRATION PPM                       25                7               25
     CO   CONCENTRATION PPM                       62                6               62
     CO2  CONCENTRATION PCT                     1.30              .92             1.30
     NOX  CONCENTRATION PPM                     46.9             12.8             46.9
     SO2  CONCENTRATION PPM                      0.0              0.0              0.0
     HC   MASS GRAMS                            1.12              .56             1.12
     CO   MASS GRAMS                            5.65              .93             5.65
     CO2  MASS GRAMS                         1865.16          2247.92          1865.16
     NOX  MASS GRAMS                            5.95             2.79             5.95
     SO2  MASS GRAMS                            0.00             0.00             0.00

     WEIGHTED MASS HC        .14 GRAMS/KILOMETRE
     WEIGHTED MASS CO        .55 GRAMS/KILOMETRE
     WEIGHTED MASS CO2    340.84 GRAMS/KILOMETRE
     WEIGHTED MASS NOX       .72 GRAMS/KILOMETRE
     WEIGHTED MASS SO2      0.00 GRAMS/KILOMETRE

   CARBON BALANCE FUEL CONSUMPTION = 14.54 LITRES PER HUNDRED KILOMETRES
   TOTAL CVS FLOW =   284.0 STD. CU. METRES
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        TABLE E-[illegible]   EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                            VEHICLE NUMBER

DATE  1/ 3/77                TIME    40 HRS.          TEST NO.   3
MODEL  1977 OLDS GAS CUTLASSUPT 7                     ENGINE 4.3 LITRE  8
DRIVER   DT                  TEST WT.  2091 KG.       GVW    0 KG
WET BULB TEMP  18 C          DRY BULB TEMP  25 C      REL. HUM.  26.8 PCT
SPEC. HUM.   5.4 GRAM/KG     BARO.  742.4 MM  HG.     MEASURED FUEL  0.00 KG

  RUN DURATION          23.28 MINUTES
  BLOWER INLET PRESS. 447.7  MM. H2O
  BLOWER DIF.  PRESS. 447.7  MM  H2O
  BLOWER INLET TEMP.      34  DEG. C
  DYNO REVOLUTIONS     21186
  BLOWER REVOLUTIONS    112321
  BLOWER CU. CM /REV.  2225

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE                26.0/2
   HC   SAMPLE  PPM                                  26
   HC   BACKGRD METER READING/SCALE                11.1/2
   HC   BACKGRD PPM                                  11
   CO   SAMPLE  METER READING/SCALE                71.5/*
   CO   SAMPLE  PPM                                  70
   CO   BACKGRD METER READING/SCALE                 1.3/*
   CO   BACKGRD PPM                                   1
   CO2  SAMPLE  METER READING/SCALE                85.6/3
   CO2  SAMPLE  PERCENT                            1.59
   CO2  BACKGRD METER READING/SCALE                 3.7/3
   CO2  BACKGRD PERCENT                             .06
   NOX  SAMPLE  METER READING/SCALE                54.0/2
   NOX  SAMPLE  PPM                                54.0
   NOX  BACKGRD METER READING/SCALE                 .7/2
   NOX  BACKGRD PPM                                  .7
   HC   CONCENTRATION PPM                            16
   CO   CONCENTRATION PPM                            66
   CO2  CONCENTRATION PCT                          1.54
   NOX  CONCENTRATION PPM                          53.4
   SO2  CONCENTRATION PPM                          0.0
   HC   MASS (GRAMS)                               2.01
   CO   MASS (GRAMS)                              16.47
   CO2  MASS (GRAMS)                            6056.31
   NOX  MASS (GRAMS)                              18.61
   SO2  MASS (GRAMS)                               0.00

HC   GRAMS/KILOMETRE        .09
CO   GRAMS/KILOMETRE        .76
CO2  GRAMS/KILOMETRE    279
NOX  GRAMS/KILOMETRE        .86

HC   GRAMS/KG OF FUEL   1.04     HC   GRAMS/MIN     .09
CO   GRAMS/KG OF FUEL    8.6     CO   GRAMS/MIN      .7
CO2  GRAMS/KG OF FUEL   3153     CO2  GRAMS/MIN     260
NOX  GRAMS/KG OF FUEL   9.64     NOX  GRAMS/MIN     .80
SO2  GRAMS/KG OF FUEL   0.00     SO2  GRAMS/MIN    0.00
CARBON BALANCE FUEL ECONOMY =    11.97 LITRES PER HUNDRED KILOMETERS
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         TABLE [illegible]  EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                            VEHICLE NUMBER

DATE  12/ 8/77              TIME    40 HRS.        TEST NO.  1
MODEL  1977 OLDS GAS CUTLASS                       ENGINE 4.3 LITRE  8
DRIVER   DT                 TEST WT.  2041 KG.     GVW    0 KG
WET BULB TEMP  19 C         DRY BULB TEMP  29 C    REL. HUM.  28.9 PCT
SPEC. HUM.   5.6 GRAMS/KG   BARO.  742.9 MM  HG.   MEASURED FUEL  0.00 KG

  RUN DURATION           12.76 MINUTES
  BLOWER INLET PRESS. 647.7  MM. H2O
  BLOWER DIF.  PRESS. 647.7  MM  H2O
  BLOWER INLET TEMP.      37  DEG. C
  DYNO REVOLUTIONS     23805
  BLOWER REVOLUTIONS    61608
  BLOWER CU. CM /REV.  2220

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE              22.1/2
   HC   SAMPLE  PPM                                22
   HC   BCKGRD  METER READING/SCALE               8.9/2
   HC   BCKGRD  PPM                                 9
   CO   SAMPLE  METER READING/SCALE              13.9/8
   CO   SAMPLE  PPM                                13
   CO   BCKGRD  METER READING/SCALE               1.8/8
   CO   BCKGRD  PPM                                 2
   CO2  SAMPLE  METER READING/SCALE              42.6/2
   CO2  SAMPLE  PERCENT                          1.88
   CO2  BCKGRD  METER READING/SCALE               1.1/2
   CO2  BCKGRD  PERCENT                           .04
   NOX  SAMPLE  METER READING/SCALE              67.8/2
   NOX  SAMPLE  PPM                              67.8
   NOX  BCKGRD  METER READING/SCALE                .7/2
   NOX  BCKGRD  PPM                                .7
   HC   CONCENTRATION PPM                          19
   CO   CONCENTRATION PPM                          11
   CO2  CONCENTRATION PCT                        1.84
   NOX  CONCENTRATION PPM                        67.2
   SO2  CNCENTRATION PPM                         0.0
   HC   MASS (GRAMS)                              .98
   CO   MASS (GRAMS)                             1.96
   CO2  MASS (GRAMS)                          3996.94
   NOX  MASS (GRAMS)                            12.98
   SO2  MASS (GRAMS)                             0.00

HC   GRAMS/KILOMETRE        .06
CO   GRAMS/KILOMETRE        .09
CO2  GRAMS/KILOMETRE     243
NOX  GRAMS/KILOMETRE        .79
SO2  GRAMS/KILOMETRE       0.00

HC   GRAMS/KG OF FUEL     .78      HC  GRAMS/MIN     .08
CO   GRAMS/KG OF FUEL     1.2      CO  GRAMS/MIN     .1
CO2  GRAMS/KG OF FUEL    3165      CO2 GRAMS/MIN    313
NOX  GRAMS/KG OF FUEL   10.28      NOX GRAMS/MIN    1.02
SO2  GRAMS/KG OF FUEL    0.00      SO2 GRAMS/MIN    0.00
CARBON BALANCE FUEL ECONOMY =   10.38 LITRES PER HUNDRED KILOMETERS
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TABLE E-41. GASEOUS EMISSIONS SUMMARY - 1976 VW DIESEL RABBIT (TRANSIENT CYCLES)

Cycle	Date	Test No.	Emission Rate, g/km HC	CO	NO_x	Fuel Cons. ℓ/100 km	Fuel Econ. mpg
1975 FTP	12/20/76	1	0.23	0.51	0.58	5.44	43.3
	12/21/76	2	0.23	0.48	0.52	5.59	42.1
	12/22/76	3	0.24	0.49	0.53	5.50	42.8
	Average		0.23	0.49	0.54	5.51	42.7
			(0.37)	(0.79)	(0.87)		
FTP_c	12/20/76	1	0.38	0.59	0.57	5.22	45.1
	12/21/76	2	0.36	0.54	0.52	5.87	40.1
	12/22/76	3	0.40	0.57	0.53	5.79	40.6
	Average		0.38	0.57	0.54	5.63	41.9
			(0.61)	(0.92)	(0.87)		
FTP_h	12/20/76	1	0.13	0.45	0.58	5.41	43.5
	12/21/76	2	0.15	0.43	0.52	5.19	45.3
	12/22/76	3	0.10	0.43	0.54	5.16	45.6
	Average		0.13	0.44	0.55	5.25	44.8
			(0.21)	(0.71)	(0.89)		
SET	12/20/76	1	0.11	0.35	0.55	4.52	52.1
	12/21/76	2	0.08	0.34	0.48	4.50	52.3
	12/22/76	3	0.08	0.34	0.48	4.50	52.3
	Average		0.09	0.34	0.50	4.51	52.2
			(0.15)	(0.55)	(0.81)		
FET	12/20/76	1	0.09	0.32	0.54	4.43	53.1
	12/21/76	2	0.08	0.32	0.51	4.41	53.4
	12/22/76	3	0.06	0.30	0.52	4.32	54.5
	Average		0.08	0.31	0.52	4.39	53.7
			(0.13)	(0.50)	(0.84)		

( ) Values in parentheses are in grams/mile

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                    TABLE F-42               VEHICLE EMISSION RESULTS
                         1975  LIGHT DUTY EMISSIONS TEST

UNIT NO. 333          TEST NO. 1          DATE 12/20/76                MFGR. CODE   -0              YR. 1976
VEHICLE MODEL  VW DIESEL RABBIT           ENGINE   1.48 LITRE 4 CYL.   TEST WT.   1020 KG           ROAD LOAD    5.4 KW
TEST TYPE  1963108719                     COMMENTS  1975 FTP 3 BAG COLD

BAROMETER 748.79 MM OF HG.                                             WET BULB TEMP  10.6 DEG. C
DRY BULB TEMP.    21.7 DEG. C                                           ABS. HUMIDITY    3.3 MILLIGRAMS/KG
REL. HUMIDITY      21 PCT.
EXHAUST EMISSIONS

                                                                       BLOWER INLET PRESS., G1 261.6 MM. H2O
    BLOWER DIF. PRESS., G2, 304.8 MM. H2O                              BLOWER INLET TEMP.    40 DEG. C

    BAG RESULTS
    BAG NO.                                          1              2              3
    BLOWER REVOLUTIONS                             7515           12908           7511
    HC    SAMPLE  METER READING/SCALE               3.9/6          4.8/3          7.6/3
    HC    SAMPLE  PPM                               124             19             30
    HC    BACKGRD METER READING/SCALE               1.5/3          1.9/3          1.3/3
    HC    BACKGRD PPM                                 6              8              5
    CO    SAMPLE  METER READING/SCALE              66.4/*         28.6/*         43.8/*
    CO    SAMPLE  PPM                                64             27             41
    CO    BACKGRD METER READING/SCALE                .6/*           .5/*           .7/*
    CO    BACKGRD PPM                                 1              0              1
    CO2   SAMPLE  METER READING/SCALE              42.1/3         34.5/3         49.3/3
    CO2   SAMPLE  PERCENT                           .72            .58            .85
    CO2   BACKGRD METER READING/SCALE               1.8/3          3.1/3          2.8/3
    CO2   BACKGRD PERCENT                           .03            .05            .04
    NOX   SAMPLE  METER READING/SCALE              36.8/2         25.2/2         37.2/2
    NOX   SAMPLE  PPM                              36.8           25.2           37.2
    NOX   BACKGRD METER READING/SCALE                .5/2           .4/2           .5/2
    NOX   BACKGRD PPM                                .5             .4             .5

    HC    CONCENTRATION PPM                         118             12             26
    CO    CONCENTRATION PPM                          62             26             40
    CO2   CONCENTRATION PCT                         .69            .53            .81
    NOX   CONCENTRATION PPM                        36.3           24.8           36.7
    HC    MASS GRAMS                                3.[illegible]   .67            .84
    CO    MASS GRAMS                                4.14           2.94           2.62
    CO2   MASS GRAMS                              724.54         956.85         852.63
    NOX   MASS GRAMS                                3.19           3.74           3.22
     HC    MASS MG                                  3.89            .67            .84

    WEIGHTED MASS HC         .23 GRAMS/KILOMETRE
    WEIGHTED MASS CO         .51 GRAMS/KILOMETRE
    WEIGHTED MASS CO2     195.38 GRAMS/KILOMETRE
    WEIGHTED MASS NOX        .58 GRAMS/KILOMETRE

CARBON BALANCE FUEL CONSUMPTION =  5.44 LITRES PER HUNDRED KILOMETRES
TOTAL CVS FLOW =   212.0 STD. CU. METRES
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TABLE E-41 VEHICLE EMISSION RESULTS
1975 LIGHT DUTY EMISSIONS TEST

UNIT NO. TEST NO. 1
VEHICLE MODEL VW DIESEL RABBIT
TEST TYPE [illegible]

DATE 12/20/76
ENGINE 1.48 LITRE 4 CYL.
COMMENTS 1975 FTP 2 BAG COLD DIED ONCE

MFGR. CODE -U
TEST WT. 1020 KG

YR. 1976
ROAD LOAD 5.4 KW

DRY BULB TEMP. 21.7 DEG. C
REL. HUMIDITY 21 PCT.
EXHAUST EMISSIONS

WET BULB TEMP 10.6 DEG. C
ABS. HUMIDITY 3.3 MILLIGRAMS/KG

BLOWER DIF. PRESS., G2, 304.8 MM. H2O

BLOWER INLET PRESS., G1 261.6 MM. H2O
BLOWER INLET TEMP. 40 DEG. C

BAG RESULTS			
BAG NO.	1	2	3
BLOWER REVOLUTIONS	7515	12908	7515
HC SAMPLE METER READING/SCALE	3.9/6	4.8/3	3.9/6
HC SAMPLE PPM	124	19	124
HC BCKGRD METER READING/SCALE	1.5/3	1.9/3	1.5/3
HC BCKGRD PPM	6	8	6
CO SAMPLE METER READING/SCALE	66.4/*	28.6/*	66.4/*
CO SAMPLE PPM	64	27	64
CO BCKGRD METER READING/SCALE	.6/*	.5/*	.6/*
CO BCKGRD PPM	1	0	1
CO2 SAMPLE METER READING/SCALE	42.1/3	34.5/3	42.1/3
CO2 SAMPLE PERCENT	.72	.58	.72
CO2 BCKGRD METER READING/SCALE	1.8/3	3.1/3	1.8/3
CO2 BCKGRD PERCENT	.03	.05	.03
NOX SAMPLE METER READING/SCALE	36.8/2	25.2/2	36.8/2
NOX SAMPLE PPM	36.8	25.2	36.8
NOX BCKGRD METER READING/SCALE	.5/2	.4/2	.5/2
NOX BCKGRD PPM	.5	.4	.5
HC CONCENTRATION PPM	118	12	118
CO CONCENTRATION PPM	62	26	62
CO2 CONCENTRATION PCT	.69	.53	.69
NOX CONCENTRATION PPM	36.3	24.8	36.3
HC MASS GRAMS	3.89	.67	3.89
CO MASS GRAMS	4.14	2.94	4.14
CO2 MASS GRAMS	724.54	956.85	724.54
NOX MASS GRAMS	3.19	3.74	3.19
HC MASS MG	3.89	.67	3.89

WEIGHTED MASS HC	.38 GRAMS/KILOMETRE
WEIGHTED MASS CO	.59 GRAMS/KILOMETRE
WEIGHTED MASS CO2	134.33 GRAMS/KILOMETRE
WEIGHTED MASS NOX	.57 GRAMS/KILOMETRE

CARBON BALANCE FUEL CONSUMPTION = 5.22 LITRES PER HUNDRED KILOMETRES
TOTAL CVS FLOW = 212.0 STD. CU. METRES

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                  TABLE B-44                  VEHICLE EMISSION RESULTS
                       1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.               TEST NO. 1        DATE 12/20/76                    MFGR. CODE   -0            YR. 1976
VEHICLE MODEL  VW DIESEL RABBIT          ENGINE   1.48 LITRE 4 CYL.       TEST WT.  1020 KG         ROAD LOAD    5.4 KW
TEST TYPE  CONFIRMATORY                  COMMENTS  1975 FTP 2 BAG HOT

BAROMETER 746.76 MM OF HG.                                               WET BULB TEMP  11.1 DEG. C
DRY BULB TEMP.     22.8 DEG. C                                            ABS. HUMIDITY    3.4 MILLIGRAMS/KG
REL. HUMIDITY      25 PCT.
EXHAUST EMISSIONS

                                                                          BLOWER INLET PRESS., G1 266.7 MM. H2O
    BLOWER DIF. PRESS., G2, 312.4 MM. H2O                                 BLOWER INLET TEMP.    42 DEG. C

    BAG RESULTS
    BAG NO.                                         1                2                3
    BLOWER REVOLUTIONS                            7511            12942             7511
    HC    SAMPLE  METER READING/SCALE             7.6/3            4.7/3            7.6/3
    HC    SAMPLE  PPM                               30               19               30
    HC    BCKGRD  METER READING/SCALE             1.3/3            1.3/3            1.3/3
    HC    BCKGRD  PPM                                5                5                5
    CO    SAMPLE  METER READING/SCALE            43.8/4           27.4/4           43.8/4
    CO    SAMPLE  PPM                               41               26               41
    CO    BCKGRD  METER READING/SCALE              .7/4             .7/4             .7/4
    CO    BCKGRD  PPM                                1                1                1
    CO2   SAMPLE  METER READING/SCALE            49.3/3           32.5/3           49.3/3
    CO2   SAMPLE  PERCENT                          .85              .54              .85
    CO2   BCKGRD  METER READING/SCALE             2.8/3            2.6/3            2.8/3
    CO2   BCKGRD  PERCENT                          .04              .04              .04
    NOX   SAMPLE  METER READING/SCALE            37.2/2           25.3/2           37.2/2
    NOX   SAMPLE  PPM                             37.2             25.3             37.2
    NOX   BCKGRD  METER READING/SCALE              .5/2             .4/2             .5/2
    NOX   BCKGRD  PPM                               .5               .4               .5

    HC    CONCENTRATION PPM                         26               14               26
    CO    CONCENTRATION PPM                         40               24               40
    CO2   CONCENTRATION PCT                        .81              .50              .81
    NOX   CONCENTRATION PPM                       36.7             24.9             36.7
    HC    MASS GRAMS                               .83              .78              .83
    CO    MASS GRAMS                              2.60             2.78             2.60
    CO2   MASS GRAMS                            845.78           849.86           845.78
    NOX   MASS GRAMS                              3.20             3.74             3.20
     HC    MASS KG                                 .83              .78              .83

    WEIGHTED MASS HC         .13 GRAMS/KILOMETRE
    WEIGHTED MASS CO         .46 GRAMS/KILOMETRE
    WEIGHTED MASS CO2     144.66 GRAMS/KILOMETRE
    WEIGHTED MASS NOX        .58 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION =  5.41 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =   210.5 STD. CU. METRES
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TABLE [illegible]  EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                    VEHICLE NUMBER

DATE 12/08/78              TIME    [illegible] HRS.      TEST NO.  1
MODEL  1978 VW DIESEL RABBIT[illegible]                  ENGINE 1.5 LITRE    4 CYL.
DRIVER   ST                TEST WT.  1020 KG.        GVW    0 KG
WET BULB TEMP  11 C        DRY BULB TEMP  18 C       REL. HUM.  39.4 PCT
SPEC. HUM.    5.3 GRAMS/KG BARO.  748.8 MM  HG.      MEASURED FUEL  0.00 KG
DISTANCE  21.7[illegible] KM         FUEL 847.3 G/LITRE   FUEL HC  RATIO 1.849

  RUN DURATION             23.28 MINUTES
  BLOWER INLET PRESS. 261.6  MM. H2O
  BLOWER DIF.  PRESS. 304.8  MM  H2O
  BLOWER INLET TEMP.      44  DEG. C
  DYNO REVOLUTIONS      31654
  BLOWER REVOLUTIONS      20766
  BLOWER CU. CM./REV.   8438

  BAG RESULTS
   HC   SAMPLE   METER READING/SCALE                       7.5/3
   HC   SAMPLE   PPM                                        30
   HC   BACKGRD  METER READING/SCALE                       1.1/3
   HC   BACKGRD  PPM                                         4
   CO   SAMPLE   METER READING/SCALE                      47.1/4
   CO   SAMPLE   PPM                                        44
   CO   BACKGRD  METER READING/SCALE                        .5/4
   CO   BACKGRD  PPM                                         0
   CO2  SAMPLE   METER READING/SCALE                      54.6/3
   CO2  SAMPLE   PERCENT                                   .96
   CO2  BACKGRD  METER READING/SCALE                       2.7/3
   CO2  BACKGRD  PERCENT                                   .04
   NOX  SAMPLE   METER READING/SCALE                      47.6/2
   NOX  SAMPLE   PPM                                      47.6
   NOX  BACKGRD  METER READING/SCALE                        .6/2
   NOX  BACKGRD  PPM                                        .6
   HC   CONCENTRATION PPM                                   26
   CO   CONCENTRATION PPM                                   43
   CO2  CONCENTRATION PCT                                  .92
   NOX  CONCENTRATION PPM                                 47.0
   SO2  CONCENTRATION PPM                                  0.0
   HC   MASS (GRAMS)                                      2.33
   CO   MASS (GRAMS)                                      7.69
   CO2  MASS (GRAMS)                                   2621.28
   NOX  MASS (GRAMS)                                     11.85
   SO2  MASS (GRAMS)                                      0.00

HC   GRAMS/KILOMETRE       .11
CO   GRAMS/KILOMETRE       .35
CO2  GRAMS/KILOMETRE    121
NOX  GRAMS/KILOMETRE       .55
SO2  GRAMS/KILOMETRE      0.00

HC   GRAMS/KG OF FUEL    2.79      HC   GRAMS/MIN        .1
CO   GRAMS/KG OF FUEL     9.2      CO   GRAMS/MIN       .3
CO2  GRAMS/KG OF FUEL    3150      CO2  GRAMS/MIN    113
NOX  GRAMS/KG OF FUEL   14.24      NOX  GRAMS/MIN    .51
SO2  GRAMS/KG OF FUEL    0.00      SO2  GRAMS/MIN   0.00

CARBON BALANCE FUEL CONSUMPTION =  4.57 LITRES PER HUNDRED KILOMETRES
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        TABLE D-[illegible]   EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                          VEHICLE NUMBER

DATE [illegible]              TIME  [illegible] HRS.        TEST NO.  1
MODEL  198[illegible] [illegible] DIESEL [illegible]                ENGINE 1.5 LITRE     4 CYL.
[illegible]   [illegible]                 TEST WT.  1020 KG.      GVW    0 KG
WET BULB TEMP  11 C           DRY BULB TEMP  2[illegible] C    REL. HUM.  19.4 PCT
ABS. HUM.   3.4 GRAMS/KG      BARO.  7[illegible] MM HG.   MEASURED FUEL  0.00 KG
DISTANCE  1[illegible] KM          FUEL [illegible] G/LITRE   FUEL HC  RATIO 1.8[illegible]

  RUN DURATION           1[illegible] MINUTES
  BLOWER INLET PRESS. [illegible]  MM. H2O
  BLOWER DIF. PRESS. [illegible]  MM  H2O
  BLOWER INLET TEMP.      [illegible]  DEG. C
  DYNO REVOLUTIONS     [illegible]
  BLOWER REVOLUTIONS     11[illegible]
  BLOWER CU. CM PER REV.  [illegible]

  BAG RESULTS
   HC   SAMPLE   METER READING/SCALE              8.1/3
   HC   SAMPLE   PPM                               32
   HC   BACKGRD  METER READING/SCALE               .8/3
   HC   BACKGRD  PPM                                3
   CO   SAMPLE   METER READING/SCALE             57.2/4
   CO   SAMPLE   PPM                               55
   CO   BACKGRD  METER READING/SCALE               .3/4
   CO   BACKGRD  PPM                                0
   CO2  SAMPLE   METER READING/SCALE             72.0/3
   CO2  SAMPLE   PERCENT                         1.30
   CO2  BACKGRD  METER READING/SCALE              3.9/3
   CO2  BACKGRD  PERCENT                          .06
   NOX  SAMPLE   METER READING/SCALE             18.9/2
   NOX  SAMPLE   PPM                             68.9
   NOX  BACKGRD  METER READING/SCALE               .6/2
   NOX  BACKGRD  PPM                               .6
   HC   CONCENTRATION PPM                          29
   CO   CONCENTRATION PPM                          53
   CO2  CONCENTRATION PCT                        1.25
   NOX  CONCENTRATION PPM                        67.9
   [illegible] CONCENTRATION PPM                         0.0
   HC   MASS GRAMS                               1.[illegible]
   CO   MASS GRAMS                               5.19
   CO2  MASS GRAMS                            1960.[illegible]
   NOX  MASS GRAMS                               [illegible].87
   [illegible]  MASS GRAMS                               0.00

HC   GRAMS/KILOMETRE        .0[illegible]
CO   GRAMS/KILOMETRE        .3[illegible]
CO2  GRAMS/KILOMETRE     11[illegible]
NOX  GRAMS/KILOMETRE        .5[illegible]
[illegible]  GRAMS/KILOMETRE      0.00

HC   GRAMS/KG OF FUEL     [illegible]      HC   GRAMS/MILE        .1
CO   GRAMS/KG OF FUEL      [illegible]      CO   GRAMS/MILE      .[illegible]
CO2  GRAMS/KG OF FUEL    31[illegible]      CO2  GRAMS/MILE     1[illegible]
NOX  GRAMS/KG OF FUEL   1[illegible]      NOX  GRAMS/MILE     .[illegible]
[illegible]  GRAMS/KG OF FUEL    [illegible]      [illegible]  GRAMS/MILE    0.00

CARBON BALANCE FUEL CONSUMPTION =  [illegible] LITRES PER HUNDRED KILOMETRES
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                        TABLE E-47            VEHICLE EMISSION RESULTS
                              1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.  ;;;        TEST NO. 2         DATE 12/21/76                 MFGR. CODE   -0                YR. 1976
VEHICLE MODEL  VW DIESEL RABBIT         ENGINE   1.48 LITRE 4 CYL.    TEST WT.  1020 KG              ROAD LOAD    5.4 KW
TEST TYPE  1763188714                   COMMENTS  1975 FTP 3 BAG COLD

BAROMETER 751.84 MM OF HG.                                       WET BULB TEMP  10.6 DEG. C
DRY BULB TEMP.   25.0 DEG. C                                      ABS. HUMIDITY   1.9 MILLIGRAMS/KG
REL. HUMIDITY     10 PCT.
EXHAUST EMISSIONS
                                                                 BLOWER INLET PRESS., G1 266.7 MM. H2O
   BLOWER DIF. PRESS., G2, 304.8 MM. H2O                         BLOWER INLET TEMP.    43 DEG. C

   BAG RESULTS
   BAG NO.                                        1              2              3
   BLOWER REVOLUTIONS                          7530          12887           7541
   HC    SAMPLE  METER READING/SCALE            3.8/6          7.3/3          8.5/3
   HC    SAMPLE  PPM                            123             29             34
   HC    BACKGRD METER READING/SCALE            3.9/3          4.1/3          1.8/3
   HC    BACKGRD PPM                             16             16              7
   CO    SAMPLE  METER READING/SCALE           62.4/*         29.0/*         42.7/*
   CO    SAMPLE  PPM                             60             27             40
   CO    BACKGRD METER READING/SCALE            1.9/*          2.1/*          1.7/*
   CO    BACKGRD PPM                              2              2              2
   CO2   SAMPLE  METER READING/SCALE           55.1/3         33.4/3         47.6/3
   CO2   SAMPLE  PERCENT                         .97            .56            .82
   CO2   BACKGRD METER READING/SCALE            3.2/3          2.4/3          3.5/3
   CO2   BACKGRD PERCENT                         .05            .04            .05
   NOX   SAMPLE  METER READING/SCALE           34.8/2         24.0/2         34.5/2
   NOX   SAMPLE  PPM                           34.8           24.0           34.5
   NOX   BACKGRD METER READING/SCALE             .7/2           .5/2           .6/2
   NOX   BACKGRD PPM                             .7             .5             .6

   HC    CONCENTRATION PPM                      108             13             27
   CO    CONCENTRATION PPM                       57             25             38
   CO2   CONCENTRATION PCT                       .92            .52            .77
   NOX   CONCENTRATION PPM                     34.2           23.5           33.9
   HC    MASS GRAMS                            3.55            .75            .89
   CO    MASS GRAMS                            3.77           2.80           2.50
   CO2   MASS GRAMS                          961.08         931.61         805.54
   NOX   MASS GRAMS                            2.87           3.39           2.86
    HC    MASS MG                              3.55            .75            .89

   WEIGHTED MASS HC        .23 GRAMS/KILOMETRE
   WEIGHTED MASS CO        .48 GRAMS/KILOMETRE
   WEIGHTED MASS CO2    149.50 GRAMS/KILOMETRE
   WEIGHTED MASS NOX       .52 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION =  5.59 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =   210.8 STD. CU. METRES
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                    TABLE  E-48            VEHICLE EMISSION RESULTS
                        1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.  !!!        TEST NO. 2          DATE 12/21/76                 MFGR. CODE   -0              YR. 1976
VEHICLE MODEL  VW DIESEL RABBIT          ENGINE   1.48 LITRE 4 CYL.      TEST WT.  1020 KG          ROAD LOAD   5.4 KW
TEST TYPE  1763188714                    COMMENTS  1975 FTP 2 BAG COLD  DIED ONCE

                                                                       WET BULB TEMP  10.6 DEG. C
BAROMETER 751.84 MM OF HG.                                              ABS. HUMIDITY   1.9 MILLIGRAMS/KG
DRY BULB TEMP.   25.0 DEG. C
REL. HUMIDITY     10 PCT.
EXHAUST EMISSIONS
                                                                       BLOWER INLET PRESS., G1 266.7 MM. H2O
                                                                       BLOWER INLET TEMP.    43 DEG. C
   BLOWER DIF. PRESS., G2, 304.8 MM. H2O

   BAG RESULTS
   BAG NO.                                    1              2              3
   BLOWER REVOLUTIONS                      7530          12887           7530
   HC    SAMPLE  METER READING/SCALE        3.8/6          7.3/3          3.8/6
   HC    SAMPLE  PPM                        123             29            123
   HC    BACKGRD METER READING/SCALE        3.9/3          4.1/3          3.9/3
   HC    BACKGRD PPM                         16             16             16
   CO    SAMPLE  METER READING/SCALE       62.4/*         29.0/*         62.4/*
   CO    SAMPLE  PPM                         60             27             60
   CO    BACKGRD METER READING/SCALE        1.9/*          2.1/*          1.9/*
   CO    BACKGRD PPM                          2              2              2
   CO2   SAMPLE  METER READING/SCALE       55.1/3         33.4/3         55.1/3
   CO2   SAMPLE  PERCENT                    .97            .56            .97
   CO2   BACKGRD METER READING/SCALE        3.2/3          2.4/3          3.2/3
   CO2   BACKGRD PERCENT                    .05            .04            .05
   NOX   SAMPLE  METER READING/SCALE       34.8/2         24.0/2         34.8/2
   NOX   SAMPLE  PPM                       34.8           24.0           34.8
   NOX   BACKGRD METER READING/SCALE         .7/2           .5/2           .7/2
   NOX   BACKGRD PPM                         .7             .5             .7

   HC    CONCENTRATION PPM                  108             13            108
   CO    CONCENTRATION PPM                   57             25             57
   CO2   CONCENTRATION PCT                  .92            .52            .92
   NOX   CONCENTRATION PPM                 34.2           23.5           34.2
   HC    MASS GRAMS                        3.55            .75           3.55
   CO    MASS GRAMS                        3.77           2.80           3.77
   CO2   MASS GRAMS                      961.08         931.61         961.08
   NOX   MASS GRAMS                        2.87           3.39           2.87
    HC    MASS MG                          3.55            .75           3.55

   WEIGHTED MASS HC        .36 GRAMS/KILOMETRE
   WEIGHTED MASS CO        .54 GRAMS/KILOMETRE
   WEIGHTED MASS CO2    156.84 GRAMS/KILOMETRE
   WEIGHTED MASS NOX       .52 GRAMS/KILOMETRE

CARBON BALANCE FUEL CONSUMPTION =  5.87 LITRES PER HUNDRED KILOMETRES
TOTAL CVS FLOW =   210.7 STD. CU. METRES
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                                   TABLE E-49              VEHICLE EMISSION RESULTS
                                             1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.  ;;;          TEST NO. 2           DATE 12/21/76                    MFGR. CODE   -0                  YR. 1976
VEHICLE MODEL  VW DIESEL RABBIT             ENGINE    1.48 LITRE 4 CYL.      TEST WT.  1020 KG                ROAD LOAD    5.4 KW
TEST TYPE  1763188714                       COMMENTS  1975 FTP 2 BAG HOT

BAROMETER 751.84 MM OF HG.                                                   WET BULB TEMP  10.0 DEG. C
DRY BULB TEMP.    23.9 DEG. C                                                 ABS. HUMIDITY   1.9 MILLIGRAMS/KG
REL. HUMIDITY      10 PCT.
EXHAUST EMISSIONS
                                                                             BLOWER INLET PRESS., G1 266.7 MM. H2O
     BLOWER DIF. PRESS., G2, 304.8 MM. H2O                                   BLOWER INLET TEMP.    43 DEG. C

     BAG RESULTS
     BAG NO.                                          1               2               3
     BLOWER REVOLUTIONS                            7541           12903            7541
     HC   SAMPLE  METER READING/SCALE             8.5/3           5.7/3           8.5/3
     HC   SAMPLE  PPM                                34              23              34
     HC   BACKGRD METER READING/SCALE             1.8/3           1.8/3           1.8/3
     HC   BACKGRD PPM                                 7               7               7
     CO   SAMPLE  METER READING/SCALE            42.7/*          27.3/*          42.7/*
     CO   SAMPLE  PPM                                40              25              40
     CO   BACKGRD METER READING/SCALE             1.7/*           1.6/*           1.7/*
     CO   BACKGRD PPM                                 2               2               2
     CO2  SAMPLE  METER READING/SCALE            47.6/3          32.3/3          47.6/3
     CO2  SAMPLE  PERCENT                           .82             .54             .82
     CO2  BACKGRD METER READING/SCALE             3.5/3           3.4/3           3.5/3
     CO2  BACKGRD PERCENT                           .05             .05             .05
     NOX  SAMPLE  METER READING/SCALE            34.5/2          23.9/2          34.5/2
     NOX  SAMPLE  PPM                              34.5            23.9            34.5
     NOX  BACKGRD METER READING/SCALE              .6/2            .6/2            .6/2
     NOX  BACKGRD PPM                                .6              .6              .6

     HC   CONCENTRATION PPM                          27              16              27
     CO   CONCENTRATION PPM                          38              24              38
     CO2  CONCENTRATION PCT                         .77             .49             .77
     NOx  CONCENTRATION PPM                        33.9            23.3            33.9
     HC   MASS GRAMS                                .89             .90             .89
     CO   MASS GRAMS                               2.50            2.68            2.50
     CO2  MASS GRAMS                             805.54          870.69          805.54
     NOX  MASS GRAMS                               2.86            3.36            2.86
      HC   MASS MG                                  .89             .90             .89

     WEIGHTED MASS HC       .15 GRAMS/KILOMETRE
     WEIGHTED MASS CO       .43 GRAMS/KILOMETRE
     WEIGHTED MASS CO2   138.90 GRAMS/KILOMETRE
     WEIGHTED MASS NOX      .52 GRAMS/KILOMETRE

    CARBON BALANCE FUEL CONSUMPTION =  5.19 LITRES PER HUNDRED KILOMETRES
    TOTAL CVS FLOW =    211.0 STD. CU. METRES
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      TABLE   E-50  EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                         VEHICLE NUMBER

DATE 12/21/76                TIME    -0 HRS.          TEST NO. 2
MODEL  1976 VW DIESEL RABBITSET-7                     ENGINE 1.5 LITRE    4 CYL.
DRIVER   DT                  TEST WT.  1020 KG.       GVW    0 KG
WET BULB TEMP  11 C          DRY BULB TEMP  24 C      REL. HUM.  15.8 PCT
SPEC. HUM.   2.9 GRAM/KG     BARO.  744.8 MM  HG.     MEASURED FUEL  0.00 KG
DISTANCE  21.738 KM          FUEL 847.3 G/LITRE    FUEL HC  RATIO 1.844

  RUN DURATION           23.35 MINUTES
  BLOWER INLET PRESS. 266.7  MM. H2O
  BLOWER DIF.  PRESS. 304.8  MM  H2O
  BLOWER INLET TEMP.     43  DEG. C
  DYNO REVOLUTIONS    30387
  BLOWER REVOLUTIONS    20837
  BLOWER CU. CM /REV.  8445

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE               6.8/3
   HC   SAMPLE  PPM                               27
   HC   BACKGRD METER READING/SCALE               1.9/3
   HC   BACKGRD PPM                               8
   CO   SAMPLE  METER READING/SCALE              45.1/*
   CO   SAMPLE  PPM                               42
   CO   BACKGRD METER READING/SCALE               1.1/*
   CO   BACKGRD PPM                               1
   CO2 SAMPLE  METER READING/SCALE               54.2/3
   CO2 SAMPLE  PERCENT                            .95
   CO2 BACKGRD METER READING/SCALE                2.9/3
   CO2 BACKGRD PERCENT                            .04
   NOX SAMPLE  METER READING/SCALE               44.6/2
   NOX SAMPLE  PPM                               44.6
   NOX BACKGRD METER READING/SCALE                1.1/2
   NOX BACKGRD PPM                                1.1
   HC   CONCENTRATION PPM                          20
   CO   CONCENTRATION PPM                          40
   CO2 CONCENTRATION PCT                          .91
   NOX CONCENTRATION PPM                         43.6
   SO2 COCENTRATION PPM                          0.0
   HC   MASS (GRAMS)                              1.81
   CO   MASS (GRAMS)                              7.37
   CO2 MASS (GRAMS)                            2613.16
   NOX MASS (GRAMS)                              10.39
   SO2 MASS (GRAMS)                               0.00

HC  GRAMS/KILOMETRE       .08
CO  GRAMS/KILOMETRE       .34
CO2 GRAMS/KILOMETRE   120
NOX GRAMS/KILOMETRE       .48
SO2 GRAMS/KILOMETRE      0.00

HC  GRAMS/KG OF FUEL   2.18     HC  GRAMS/MIN        .1
CO  GRAMS/KG OF FUEL    8.9     CO  GRAMS/MIN       .3
CO2 GRAMS/KG OF FUEL   3152     CO2 GRAMS/MIN     112
NOX GRAMS/KG OF FUEL  12.53     NOX GRAMS/MIN      .44
SO2 GRAMS/KG OF FUEL   0.00     SO2 GRAMS/MIN    0.00

CARBON BALANCE FUEL CONSUMPTION =  4.50 LITRES PER HUNDRED KILOMETRES
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      TABLE E-51  EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                         VEHICLE NUMBER

DATE 12/21/76               TIME     -0 HRS.         TEST NO.  5
MODEL  1976 VW DIESEL RABBTFET                       ENGINE 1.5 LITRE    4 CYL.
DRIVER   DT                 TEST WT.  1020 KG.       GVW    0 KG
WET BULB TEMP  11 C         DRY BULB TEMP  23 C      REL. HUM.  17.6 PCT
SPEC. HUM.   3.2 GRAM/KG    BARO.  749.8 MM  HG.    MEASURED FUEL  0.00 KG
DISTANCE  16.476 KM         FUEL 847.3 G/LITRE   FUEL HC  RATIO 1.844

  RUN DURATION         12.75 MINUTES
  BLOWER INLET PRESS. 266.7  MM. H2O
  BLOWER DIF.  PRESS. 304.8  MM  H2O
  BLOWER INLET TEMP.     43  DEG. C
  DYNO REVOLUTIONS     23530
  BLOWER REVOLUTIONS    11375
  BLOWER CU. CM /REV.  8445

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE              7.8/3
   HC   SAMPLE  PPM                               31
   HC   BACKGRD METER READING/SCALE               .9/3
   HC   BACKGRD PPM                                4
   CO   SAMPLE  METER READING/SCALE             59.1/*
   CO   SAMPLE  PPM                               57
   CO   BACKGRD METER READING/SCALE              1.6/*
   CO   BACKGRD PPM                                2
   CO2  SAMPLE  METER READING/SCALE             70.6/3
   CO2  SAMPLE  PERCENT                         1.28
   CO2  BACKGRD METER READING/SCALE              3.0/3
   CO2  BACKGRD PERCENT                          .05
   NOX  SAMPLE  METER READING/SCALE             64.5/2
   NOX  SAMPLE  PPM                             64.5
   NOX  BACKGRD METER READING/SCALE              .6/2
   NOX  BACKGRD PPM                               .6
   HC   CONCENTRATION PPM                         28
   CO   CONCENTRATION PPM                         53
   CO2  CONCENTRATION PCT                       1.23
   NOX  CONCENTRATION PPM                       64.0
   SO2  COCENTRATION PPM                        0.0
   HC   MASS (GRAMS)                            1.37
   CO   MASS (GRAMS)                            5.32
   CO2  MASS (GRAMS)                         1941.27
   NOX  MASS (GRAMS)                            8.37
   SO2  MASS (GRAMS)                            0.00

HC   GRAMS/KILOMETRE       .08
CO   GRAMS/KILOMETRE       .32
CO2  GRAMS/KILOMETRE   118
NOX  GRAMS/KILOMETRE       .51
SO2  GRAMS/KILOMETRE      0.00

HC   GRAMS/KG OF FUEL   2.23     HC   GRAMS/MIN       .1
CO   GRAMS/KG OF FUEL    8.6     CO   GRAMS/MIN      .4
CO2  GRAMS/KG OF FUEL   3152     CO2  GRAMS/MIN     152
NOX  GRAMS/KG OF FUEL  13.60     NOX  GRAMS/MIN     .66
SO2  GRAMS/KG OF FUEL   0.00     SO2  GRAMS/MIN    0.00

CARBON BALANCE FUEL CONSUMPTION =  4.41 LITRES PER HUNDRED KILOMETRES
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                              TABLE  E-52                  VEHICLE EMISSION RESULTS
                                         1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.  ???          TEST NO. 3          DATE 12/22/76                     MFGR. CODE    -0                       YR. 1976
VEHICLE MODEL  VW DIESEL RABBIT            ENGINE    1.48 LITRE 4 CYL.       TEST WT.  1020 KG                      ROAD LOAD    5.4 KW
TEST TYPE  1763188714                      COMMENTS  1975 FTP 3 BAG COLD

BAROMETER 746.25 MM OF HG.                                                   WET BULB TEMP  11.1 DEG. C
DRY BULB TEMP.    22.8 DEG. C                                                 ABS. HUMIDITY   3.4 MILLIGRAMS/KG
REL. HUMIDITY     20 PCT.
EXHAUST EMISSIONS
                                                                             BLOWER INLET PRESS., G1 254.0 MM. H2O
    BLOWER DIF. PRESS., G2, 304.8 MM. H2O                                    BLOWER INLET TEMP.    43 DEG. C

    BAG RESULTS
    BAG NO.                                           1              2              3
    BLOWER REVOLUTIONS                             7521          12906           7535
    HC    SAMPLE  METER READING/SCALE              4.1/6          6.0/3          7.6/3
    HC    SAMPLE  PPM                              132             24             30
    HC    BACKGRD METER READING/SCALE              2.5/3          2.5/3          2.5/3
    HC    BACKGRD PPM                              10             10             10
    CO    SAMPLE  METER READING/SCALE             68.2/*         28.2/*         41.9/*
    CO    SAMPLE  PPM                              66             26             39
    CO    BACKGRD METER READING/SCALE              2.7/*          1.2/*          1.1/*
    CO    BACKGRD PPM                               3              1              1
    CO2   SAMPLE  METER READING/SCALE             54.5/3         33.4/3         47.4/3
    CO2   SAMPLE  PERCENT                          .95            .56            .82
    CO2   BACKGRD METER READING/SCALE              2.8/3          2.7/3          3.9/3
    CO2   BACKGRD PERCENT                          .04            .04            .06
    NOX   SAMPLE  METER READING/SCALE             35.3/2         23.2/2         34.5/2
    NOX   SAMPLE  PPM                             35.3           23.2           34.5
    NOX   BACKGRD METER READING/SCALE               .5/2           .4/2           .4/2
    NOX   BACKGRD PPM                               .5             .4             .4

    HC    CONCENTRATION PPM                        123             14             21
    CO    CONCENTRATION PPM                         62             25             37
    CO2   CONCENTRATION PCT                         .91            .52            .76
    NOX   CONCENTRATION PPM                        34.8           22.8           34.1
    HC    MASS GRAMS                               3.99            .80            .69
    CO    MASS GRAMS                               4.08           2.78           2.46
    CO2   MASS GRAMS                             947.24         918.90         789.52
    NOX   MASS GRAMS                               3.03           3.40           2.97
     HC    MASS MG                                 3.99            .80            .69

    WEIGHTED MASS HC        .24 GRAMS/KILOMETRE
    WEIGHTED MASS CO        .49 GRAMS/KILOMETRE
    WEIGHTED MASS CO2    147.19 GRAMS/KILOMETRE
    WEIGHTED MASS NOX       .53 GRAMS/KILOMETRE

   CARBON BALANCE FUEL CONSUMPTION =  5.50 LITRES PER HUNDRED KILOMETRES
   TOTAL CVS FLOW =    209.4 STD. CU. METRES
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                    TABLE  E-53            VEHICLE EMISSION RESULTS
                          1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.  111        TEST NO. 3        DATE 12/22/76                  MFGR. CODE   -0                   YR. 1976
VEHICLE MODEL  VW DIESEL RABBIT        ENGINE   1.48 LITRE 4 CYL.     TEST WT.  1020 KG                ROAD LOAD   5.4 KW
TEST TYPE  1763188714                  COMMENTS  1975 FTP 2 BAG COLD DIED ONCE

BAROMETER 746.25 MM OF HG.                                          WET BULB TEMP  11.1 DEG. C
DRY BULB TEMP.   22.8 DEG. C                                         ABS. HUMIDITY   3.4 MILLIGRAMS/KG
REL. HUMIDITY     20 PCT.
EXHAUST EMISSIONS
                                                                    BLOWER INLET PRESS., G1 254.0 MM. H2O
   BLOWER DIF. PRESS., G2, 304.8 MM. H2O                            BLOWER INLET TEMP.    43 DEG. C

   BAG RESULTS
   BAG NO.                                   1             2             3
   BLOWER REVOLUTIONS                       7521         12906          7521
   HC    SAMPLE  METER READING/SCALE         4.1/6         6.0/3         4.1/6
   HC    SAMPLE  PPM                        132            24           132
   HC    BACKGRD METER READING/SCALE         2.5/3         2.5/3         2.5/3
   HC    BACKGRD PPM                         10            10            10
   CO    SAMPLE  METER READING/SCALE        68.2/*        28.2/*        68.2/*
   CO    SAMPLE  PPM                         66            26            66
   CO    BACKGRD METER READING/SCALE         2.7/*         1.2/*         2.7/*
   CO    BACKGRD PPM                          3             1             3
   CO2   SAMPLE  METER READING/SCALE        54.5/3        33.4/3        54.5/3
   CO2   SAMPLE  PERCENT                     .95           .56           .95
   CO2   BACKGRD METER READING/SCALE         2.8/3         2.7/3         2.8/3
   CO2   BACKGRD PERCENT                     .04           .04           .04
   NOX   SAMPLE  METER READING/SCALE        35.3/2        23.2/2        35.3/2
   NOX   SAMPLE  PPM                        35.3          23.2          35.3
   NOX   BACKGRD METER READING/SCALE          .5/2          .4/2          .5/2
   NOX   BACKGRD PPM                          .5            .4            .5

   HC    CONCENTRATION PPM                  123            14           123
   CO    CONCENTRATION PPM                   62            25            62
   CO2   CONCENTRATION PCT                   .91           .52           .91
   NOX   CONCENTRATION PPM                  34.8          22.8          34.8
   HC    MASS GRAMS                         3.99           .80          3.99
   CO    MASS GRAMS                         4.08          2.78          4.08
   CO2   MASS GRAMS                       947.24        918.90        947.24
   NOX   MASS GRAMS                         3.03          3.40          3.03
    HC     MASS MG                          3.99           .80          3.99

   WEIGHTED MASS HC        .40 GRAMS/KILOMETRE
   WEIGHTED MASS CO        .57 GRAMS/KILOMETRE
   WEIGHTED MASS CO2   154.64 GRAMS/KILOMETRE
   WEIGHTED MASS NOX       .53 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION =  5.79 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =    209.3 STD. CU. METRES
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                    TABLE  E-54            VEHICLE EMISSION RESULTS
                         1975  LIGHT DUTY EMISSIONS TEST

UNIT NO.  ;;;        TEST NO. 3         DATE 12/22/76                 MFGR. CODE   -0              YR. 1976
VEHICLE MODEL  VW DIESEL RABBIT         ENGINE   1.48 LITRE 4 CYL.    TEST WT.  1020 KG            ROAD LOAD   5.4 KW
TEST TYPE  1763188714                   COMMENTS  1975 FTP 2 BAG HOT

BAROMETER 746.25 MM OF HG.                                      WET BULB TEMP  11.1 DEG. C
DRY BULB TEMP.   23.9 DEG. C                                     ABS. HUMIDITY   3.0 MILLIGRAMS/KG
REL. HUMIDITY     16 PCT.
EXHAUST EMISSIONS

                                                                BLOWER INLET PRESS., G1 266.7 MM. H2O
   BLOWER DIF. PRESS., G2, 304.8 MM. H2O                        BLOWER INLET TEMP.    43 DEG. C

   BAG RESULTS
   BAG NO.                                        1            2            3
   BLOWER REVOLUTIONS                           7535        12912         7535
   HC    SAMPLE  METER READING/SCALE             7.6/3        5.1/3        7.6/3
   HC    SAMPLE  PPM                             30           21           30
   HC    BACKGRD METER READING/SCALE             2.5/3        2.8/3        2.5/3
   HC    BACKGRD PPM                             10           11           10
   CO    SAMPLE  METER READING/SCALE            41.9/*       27.6/*       41.9/*
   CO    SAMPLE  PPM                             39           26           39
   CO    BACKGRD METER READING/SCALE             1.1/*        1.5/*        1.1/*
   CO    BACKGRD PPM                             1            1            1
   CO2   SAMPLE  METER READING/SCALE            47.4/3       32.9/3       47.4/3
   CO2   SAMPLE  PERCENT                         .82          .55          .82
   CO2   BACKGRD METER READING/SCALE             3.9/3        3.6/3        3.9/3
   CO2   BACKGRD PERCENT                         .06          .06          .06
   NOX   SAMPLE  METER READING/SCALE            34.5/2       24.4/2       34.5/2
   NOX   SAMPLE  PPM                            34.5         24.4         34.5
   NOX   BACKGRD METER READING/SCALE              .4/2         .4/2         .4/2
   NOX   BACKGRD PPM                              .4           .4           .4

   HC    CONCENTRATION PPM                       21           10           21
   CO    CONCENTRATION PPM                       37           24           37
   CO2   CONCENTRATION PCT                       .76          .49          .76
   NOX   CONCENTRATION PPM                      34.1         24.0         34.1
   HC    MASS GRAMS                              .68          .54          .68
   CO    MASS GRAMS                             2.46         2.69         2.46
   CO2   MASS GRAMS                           788.46       878.35       788.46
   NOX   MASS GRAMS                             2.93         3.53         2.93
    HC    MASS MG                                .68          .54          .68

   WEIGHTED MASS HC        .10 GRAMS/KILOMETRE
   WEIGHTED MASS CO        .43 GRAMS/KILOMETRE
   WEIGHTED MASS CO2    138.12 GRAMS/KILOMETRE
   WEIGHTED MASS NOX       .54 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION =  5.16 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =   209.3 STD. CU. METRES
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      TABLE E-55   EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                          VEHICLE NUMBER

DATE 12/22/76               TIME    -0 HRS.        TEST NO. 3
MODEL  1976 VW DIESEL RABBTSET-7                   ENGINE 1.5 LITRE    4 CYL.
DRIVER   DT                 TEST WT.  1020 KG.     GVW    0 KG
WET BULB TEMP  12 C         DRY BULB TEMP  24 C    REL. HUM.  17.0 PCT
SPEC. HUM.   3.3 GRAM/KG    BARO.  746.3 MM  HG.   MEASURED FUEL  0.00 KG
DISTANCE  21.738 KM         FUEL 847.3 G/LITRE   FUEL HC  RATIO 1.844

  RUN DURATION          23.28 MINUTES
  BLOWER INLET PRESS. 266.7  MM. H2O
  BLOWER DIF.  PRESS. 304.8  MM  H2O
  BLOWER INLET TEMP.     43  DEG. C
  DYNO REVOLUTIONS     30665
  BLOWER REVOLUTIONS     20784
  BLOWER CU. CM /REV.  8443

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE             8.9/3
   HC   SAMPLE  PPM                              36
   HC   BACKGRD METER READING/SCALE             4.7/3
   HC   BACKGRD PPM                              19
   CO   SAMPLE  METER READING/SCALE            46.0/*
   CO   SAMPLE  PPM                              43
   CO   BACKGRD METER READING/SCALE              .9/*
   CO   BACKGRD PPM                               1
   CO2 SAMPLE  METER READING/SCALE             55.7/3
   CO2 SAMPLE  PERCENT                          .48
   CO2 BACKGRD METER READING/SCALE             4.5/3
   CO2 BACKGRD PERCENT                          .07
   NOX SAMPLE  METER READING/SCALE             44.0/2
   NOX SAMPLE  PPM                             44.0
   NOX BACKGRD METER READING/SCALE              .4/2
   NOX BACKGRD PPM                               .4
   HC   CONCENTRATION PPM                        18
   CO   CONCENTRATION PPM                        41
   CO2 CONCENTRATION PCT                        .91
   NOX CONCENTRATION PPM                       43.6
   SO2 COCENTRATION PPM                        0.0
   HC   MASS (GRAMS)                           1.65
   CO   MASS (GRAMS)                           7.50
   CO2 MASS (GRAMS)                         2611.78
   NOX MASS (GRAMS)                           10.42
   SO2 MASS (GRAMS)                            0.00

HC  GRAMS/KILOMETRE      .08
CO  GRAMS/KILOMETRE      .34
CO2 GRAMS/KILOMETRE   120
NOX GRAMS/KILOMETRE      .48
SO2 GRAMS/KILOMETRE     0.00

HC  GRAMS/KG OF FUEL   1.99    HC  GRAMS/MIN       .1
CO  GRAMS/KG OF FUEL    9.0    CO  GRAMS/MIN      .3
CO2 GRAMS/KG OF FUEL   3153    CO2 GRAMS/MIN     112
NOX GRAMS/KG OF FUEL  12.57    NOX GRAMS/MIN     .45
SO2 GRAMS/KG OF FUEL   0.00    SO2 GRAMS/MIN    0.00

CARBON BALANCE FUEL CONSUMPTION =  4.50 LITRES PER HUNDRED KILOMETRES
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      TABLE E-56   EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                            VEHICLE NUMBER

                             TIME    -0 HRS.        TEST NO.  3
DATE 12/22/76                                       ENGINE 1.5 LITRE    4 CYL.
MODEL  1976 VW DIESEL RABBITFET                     GVW    0 KG
DRIVER   DT                  TEST WT.  1020 KG.     REL. HUM.  28.2 PCT
WET BULB TEMP  12 C          DRY BULB TEMP  22 C    MEASURED FUEL  0.00 KG
SPEC. HUM.   4.8 GRAM/KG     BARO.  746.3 MM  HG.   FUEL HC  RATIO 1.844
DISTANCE  16.476 KM          FUEL 847.3 G/LITRE

  RUN DURATION          12.77 MINUTES
  BLOWER INLET PRESS. 266.7  MM. H20
  BLOWER DIF.  PRESS. 312.4  MM  H20
  BLOWER INLET TEMP.     45  DEG. C
  DYNO REVOLUTIONS    23433
  BLOWER REVOLUTIONS    11397
  BLOWER CU. CM /REV.  8423

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE              8.4/3
   HC  SAMPLE  PPM                                34
   HC  BACKGRD METER READING/SCALE              3.3/3
   HC  BACKGRD PPM                                13
   CO  SAMPLE  METER READING/SCALE             55.9/*
   CO  SAMPLE  PPM                                53
   CO  BACKGRD METER READING/SCALE               .6/*
   CO  BACKGRD PPM                                 1
   CO2 SAMPLE  METER READING/SCALE             70.6/3
   CO2 SAMPLE  PERCENT                          1.28
   CO2 BACKGRD METER READING/SCALE              3.8/3
   CO2 BACKGRD PERCENT                           .06
   NOX SAMPLE  METER READING/SCALE             63.5/2
   NOX SAMPLE  PPM                             63.5
   NOX BACKGRD METER READING/SCALE               .5/2
   NOX BACKGRD PPM                                .5
   HC  CONCENTRATION PPM                          22
   CO  CONCENTRATION PPM                          51
   CO2 CONCENTRATION PCT                        1.22
   NOX CONCENTRATION PPM                        63.0
   SO2 COCENTRATION PPM                          0.0
   HC  MASS (GRAMS)                             1.05
   CO  MASS (GRAMS)                             5.02
   CO2 MASS (GRAMS)                          1903.02
   NOX MASS (GRAMS)                             8.53
   SO2 MASS (GRAMS)                             0.00

 HC  GRAMS/KILOMETRE       .06
 CO  GRAMS/KILOMETRE       .30
 CO2 GRAMS/KILOMETRE   115
 NOX GRAMS/KILOMETRE       .52
 SO2 GRAMS/KILOMETRE      0.00

 HC  GRAMS/KG OF FUEL   1.74     HC  GRAMS/MIN       .1
 CO  GRAMS/KG OF FUEL    8.3     CO  GRAMS/MIN      .4
 CO2 GRAMS/KG OF FUEL   3154     CO2 GRAMS/MIN    149
 NOX GRAMS/KG OF FUEL  14.14     NOX GRAMS/MIN     .67
 SO2 GRAMS/KG OF FUEL   0.00     SO2 GRAMS/MIN   0.00

 CARBON BALANCE FUEL CONSUMPTION =  4.32 LITRES PER HUNDRED KILOMETRES
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TABLE E-57. GASEOUS EMISSIONS SUMMARY - 1977 VW RABBIT (GASOLINE) (TRANSIENT CYCLES)

		Test	Emission Rate, g/km			Fuel Cons.	Fuel Econ.
Cycle	Date	No.	HC	CO	NO_x	ℓ/100 km	mpg
1975 FTP	12/29/76	1	0.14	2.01	0.62	9.69	24.28
	12/30/76	2	0.14	2.56	0.61	9.47	24.85
	1/3/77	3	0.14	2.32	0.65	9.51	24.74
	Average		0.14	2.30	0.63	9.56	24.62
			(0.23)	(3.70)	(1.01)		
Final Test (RTP)			(0.17)	(2.0)	(0.84)		21.3
FTP_c	12/29/76	1	0.21	3.31	0.68	10.22	23.02
	12/30/76	2	0.23	4.15	0.69	10.24	22.98
	1/3/77	3	0.09	1.14	0.64	9.27	25.38
	Average		0.18	2.87	0.67	9.91	23.79
			(0.30)	(4.62)	(1.08)		
FTP_h	12/29/76	1	0.09	0.98	0.60	8.98	26.20
	12/30/76	2	0.08	1.47	0.55	8.90	26.44
	1/3/77	3	0.18	3.36	0.65	9.96	23.62
	Average		0.12	1.94	0.60	9.60	25.42
			(0.19)	(3.12)	(0.96)		
SET	12/29/76	1	0.03	0.13	1.02	7.41	31.75
	12/30/76	2	0.03	0.29	1.03	7.45	31.58
	1/3/77	3	0.02	0.14	0.98	7.42	31.71
	Average		0.03	0.19	1.01	7.43	31.68
			(0.05)	(0.30)	(1.62)		
FET	12/29/76	1	0.03	0.02	1.19	6.43	36.59
	12/30/76	2	0.03	0.05	1.24	6.54	35.98
	1/3/77	3	0.02	0.02	1.22	6.61	35.60
	Average		0.03	0.03	1.22	6.53	36.06
			(0.05)	(0.05)	(1.96)		
Final Test (RTP)							34.5

( ) Values in parentheses are in grams/mile

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                         TABLE  E-58              VEHICLE EMISSION RESULTS
                                              1975  LIGHT DUTY EMISSIONS TEST
UNIT NO.  650         TEST NO. 1   75 FTP  DATE 12/29/76                  MFGR. CODE   -0                  YR.  1977
VEHICLE MODEL  VW GAS RABBIT               ENGINE   1.59 LITRE 4          CURB WT.    884 KG                GVM     0 KG

BAROMETER 741.68 MM OF HG.                                           WET BULB TEMP  12.8 DEG. C
DRY BULB TEMP.    25.6 DEG. C                                         ABS. HUMIDITY   4.0 GRAMS/KG
REL. HUMIDITY      19 PCT.

EXHAUST EMISSIONS
                                                                     BLOWER INLET PRESS., G1 604.5 MM. H20
   BLOWER DIF. PRESS., G2, 599.4 MM. H20                             BLOWER INLET TEMP.    40 DEG. C
   BAG RESULTS
   BAG NO.                                       1                2               3
   BLOWER REVOLUTIONS                          40619            70002           40708
   HC    SAMPLE  METER READING/SCALE            55.5/2           18.7/2          28.3/2
   HC    SAMPLE  PPM                            55               19              28
   HC    BACKGRD METER READING/SCALE            11.0/2           13.2/2          18.0/2
   HC    BACKGRD PPM                            11               13              18
   CO    SAMPLE  METER READING/SCALE            80.0/*           64.2/*          50.1/*
   CO    SAMPLE  PPM                            363              62              47
   CO    BACKGRD METER READING/SCALE            2.9/*            2.1/*           5.1/*
   CO    BACKGRD PPM                            9                6               5
   CO2   SAMPLE  METER READING/SCALE            56.2/3           39.5/3          47.7/3
   CO2   SAMPLE  PERCENT                        .99              .67             .82
   CO2   BACKGRD METER READING/SCALE            4.0/3            4.3/3           3.1/3
   CO2   BACKGRD PERCENT                        .06              .07             .05
   NOX   SAMPLE  METER READING/SCALE            47.4/2           13.1/2          37.0/2
   NOX   SAMPLE  PPM                            47.4             13.1            37.0
   NOX   BACKGRD METER READING/SCALE            .7/2             1.1/2           .8/2
   NOX   BACKGRD PPM                            .7               1.1             .8
   SO2   SAMPLE  METER READING/SCALE            -0.0/*           -0.0/*          -0.0/*
   SO2   SAMPLE  PPM                            -0.0             -0.0            -0.0
   SO2   BACKGRD METER READING/SCALE            -0.0/*           -0.0/*          -0.0/*
   SO2   BACKGRD PPM                            -0.0             -0.0            -0.0

   HC    CONCENTRATION PPM                      45               6               11
   CO    CONCENTRATION PPM                      346              55              42
   CO2   CONCENTRATION PCT                      .93              .61             .78
   NOX   CONCENTRATION PPM                      46.8             12.1            36.2
   SO2   CONCENTRATION PPM                      0.0              0.0             0.0
   HC    MASS GRAMS                             2.03             .48             .51
   CO    MASS GRAMS                             31.35            8.56            3.79
   CO2   MASS GRAMS                           1330.87          1492.30         1115.08
   NOX   MASS GRAMS                             5.69             2.53            4.42
   SO2   MASS GRAMS                             0.00             0.00            0.00

   WEIGHTED MASS HC        .14 GRAMS/KILOMETRE
   WEIGHTED MASS CO       2.01 GRAMS/KILOMETRE
   WEIGHTED MASS CO2    223.76 GRAMS/KILOMETRE
   WEIGHTED MASS NOX       .62 GRAMS/KILOMETRE
   WEIGHTED MASS SO2      0.00 GRAMS/KILOMETRE

CARBON BALANCE FUEL CONSUMPTION =  9.69 LITRES PER HUNDRED KILOMETRES
TOTAL CVS FLOW =   289.6 STD. CU. METRES
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                    TABLE  E-59            VEHICLE EMISSION RESULTS
                                       1975  LIGHT DUTY EMISSIONS TEST
UNIT NO.  650        TEST NO. 1  FTP Cold  DATE 12/29/76                   MFGR. CODE   -0                YR.  1977
VEHICLE MODEL  VW GAS RABBIT               ENGINE   1.59 LITRE 4           CURB WT.    884 KG               GVM     0 KG

BAROMETER 741.68 MM OF HG.                                             WET BULB TEMP  12.8 DEG. C
DRY BULB TEMP.    25.6 DEG. C                                           ABS. HUMIDITY    4.0 GRAMS/KG
REL. HUMIDITY      19 PCT.

EXHAUST EMISSIONS
                                                                       BLOWER INLET PRESS., G1 604.5 MM. H20
     BLOWER DIF. PRESS., G2, 599.4 MM. H20                             BLOWER INLET TEMP.   40 DEG. C
     BAG RESULTS
     BAG NO.                                          1            2            3
     BLOWER REVOLUTIONS                           40619        70002        40619
     HC   SAMPLE  METER READING/SCALE             55.5/2       18.7/2       55.5/2
     HC   SAMPLE  PPM                              55           19           55
     HC   BACKGRD METER READING/SCALE             11.0/2       13.2/2       11.0/2
     HC   BACKGRD PPM                              11           13           11
     CO   SAMPLE  METER READING/SCALE             80.0/*       64.2/*       80.0/*
     CO   SAMPLE  PPM                             363           62          363
     CO   BACKGRD METER READING/SCALE              2.9/*        2.1/*        2.9/*
     CO   BACKGRD PPM                               9            6            9
     CO2  SAMPLE  METER READING/SCALE             56.2/3       39.5/3       56.2/3
     CO2  SAMPLE  PERCENT                          .99          .67          .99
     CO2  BACKGRD METER READING/SCALE              4.0/3        4.3/3        4.0/3
     CO2  BACKGRD PERCENT                          .06          .07          .06
     NOX  SAMPLE  METER READING/SCALE             47.4/2       13.1/2       47.4/2
     NOX  SAMPLE  PPM                             47.4         13.1         47.4
     NOX  BACKGRD METER READING/SCALE               .7/2        1.1/2         .7/2
     NOX  BACKGRD PPM                               .7          1.1           .7
     SO2  SAMPLE  METER READING/SCALE             -0.0/*       -0.0/*       -0.0/*
     SO2  SAMPLE  PPM                             -0.0         -0.0         -0.0
     SO2  BACKGRD METER READING/SCALE             -0.0/*       -0.0/*       -0.0/*
     SO2  BACKGRD PPM                             -0.0         -0.0         -0.0

     HC   CONCENTRATION PPM                        45            6           45
     CO   CONCENTRATION PPM                       346           55          346
     CO2  CONCENTRATION PCT                        .93          .61          .93
     NOX  CONCENTRATION PPM                       46.8         12.1         46.8
     SO2  CONCENTRATION PPM                        0.0          0.0          0.0
     HC   MASS GRAMS                              2.03          .48         2.03
     CO   MASS GRAMS                             31.35         8.56        31.35
     CO2  MASS GRAMS                           1330.87      1492.30      1330.87
     NOX  MASS GRAMS                              5.69         2.53         5.69
     SO2  MASS GRAMS                              0.00         0.00         0.00

     WEIGHTED MASS HC       .21 GRAMS/KILOMETRE
     WEIGHTED MASS CO      3.31 GRAMS/KILOMETRE
     WEIGHTED MASS CO2   233.95 GRAMS/KILOMETRE
     WEIGHTED MASS NOX      .68 GRAMS/KILOMETRE
     WEIGHTED MASS SO2     0.00 GRAMS/KILOMETRE

   CARBON BALANCE FUEL CONSUMPTION = 10.22 LITRES PER HUNDRED KILOMETRES
   TOTAL CVS FLOW =    289.5 STD. CU. METRES
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                         TABLE  E-60              VEHICLE EMISSION RESULTS
                                              1975  LIGHT DUTY EMISSIONS TEST
UNIT NO.  650        TEST NO. 1   FTP Hot   DATE 12/29/76                      MFGR. CODE   -0                  YR.  1977
VEHICLE MODEL  VW GAS RABBIT                ENGINE   1.59 LITRE 4              CURB WT.    884 KG               GVM      0 KG

BAROMETER 741.68 MM OF HG.                                                   WET BULB TEMP  14.4 DEG. C
DRY BULB TEMP.    24.4 DEG. C                                                 ABS. HUMIDITY   6.2 GRAMS/KG
REL. HUMIDITY      32 PCT.

EXHAUST EMISSIONS
                                                                             BLOWER INLET PRESS., G1 602.0 MM. H2O
    BLOWER DIF. PRESS., G2, 602.0 MM. H2O                                    BLOWER INLET TEMP.   41 DEG. C
    BAG RESULTS
    BAG NO.                                        1                 2                 3
    BLOWER REVOLUTIONS                         40708             69899             40708
    HC    SAMPLE  METER READING/SCALE           28.3/2            25.4/2            28.3/2
    HC    SAMPLE  PPM                           28                25                28
    HC    BACKGRD METER READING/SCALE           18.0/2            19.0/2            18.0/2
    HC    BACKGRD PPM                           18                19                18
    CO    SAMPLE  METER READING/SCALE           50.1/*            58.2/*            50.1/*
    CO    SAMPLE  PPM                           47                56                47
    CO    BACKGRD METER READING/SCALE            5.1/*             2.8/*             5.1/*
    CO    BACKGRD PPM                            5                 3                 5
    CO2   SAMPLE  METER READING/SCALE           47.7/3            37.1/3            47.7/3
    CO2   SAMPLE  PERCENT                        .82               .62               .82
    CO2   BACKGRD METER READING/SCALE            3.1/3             3.6/3             3.1/3
    CO2   BACKGRD PERCENT                        .05               .06               .05
    NOX   SAMPLE  METER READING/SCALE           37.0/2            11.9/2            37.0/2
    NOX   SAMPLE  PPM                           37.0              11.9              37.0
    NOX   BACKGRD METER READING/SCALE             .8/2              .6/2              .8/2
    NOX   BACKGRD PPM                             .8                .6                .8
    SO2   SAMPLE  METER READING/SCALE           -0.0/*            -0.0/*            -0.0/*
    SO2   SAMPLE  PPM                           -0.0              -0.0              -0.0
    SO2   BACKGRD METER READING/SCALE           -0.0/*            -0.0/*            -0.0/*
    SO2   BACKGRD PPM                           -0.0              -0.0              -0.0

    HC    CONCENTRATION PPM                      11                 7                11
    CO    CONCENTRATION PPM                      42                52                42
    CO2   CONCENTRATION PCT                      .78               .57               .78
    NOX   CONCENTRATION PPM                     36.2              11.3              36.2
    SO2   CONCENTRATION PPM                      0.0               0.0               0.0
    HC    MASS GRAMS                             .51               .56               .51
    CO    MASS GRAMS                            3.77              8.07              3.77
    CO2   MASS GRAMS                         1114.10           1404.66           1114.10
    NOX   MASS GRAMS                            4.70              2.52              4.70
    SO2   MASS GRAMS                            0.00              0.00              0.00

    WEIGHTED MASS HC        .09 GRAMS/KILOMETRE
    WEIGHTED MASS CO        .98 GRAMS/KILOMETRE
    WEIGHTED MASS CO2    208.72 GRAMS/KILOMETRE
    WEIGHTED MASS NOX       .60 GRAMS/KILOMETRE
    WEIGHTED MASS SO2      0.00 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION =  8.98 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =    289.3 STD. CU. METRES
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       TABLE  E-61  EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                          VEHICLE NUMBER 650

DATE 12/29/76               TIME    -0 HRS.        TEST NO. 1
MODEL  1977 VW GAS RABBIT  SET-7                   ENGINE 1.6 LITRE  4
DRIVER   DT                TEST WT.  1020 KG.      GVW    0 KG
WET BULB TEMP  14 C        DRY BULB TEMP  26 C     REL. HUM.  22.9 PCT
SPEC. HUM.   4.9 GRAM/KG   BARO.  741.7 MM  HG.    MEASURED FUEL  0.00 KG

  RUN DURATION          23.25 MINUTES
  BLOWER INLET PRESS. 599.4  MM. H2O
  BLOWER DIF.  PRESS. 596.9  MM  H2O
  BLOWER INLET TEMP.     41  DEG. C
  DYNO REVOLUTIONS    30956
  BLOWER REVOLUTIONS   112253
  BLOWER CU. CM /REV.  2234

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE          26.2/2
   HC  SAMPLE  PPM                          26
   HC  BACKGRD METER READING/SCALE          22.0/2
   HC  BACKGRD PPM                          22
   CO  SAMPLE  METER READING/SCALE          14.1/*
   CO  SAMPLE  PPM                          13
   CO  BACKGRD METER READING/SCALE           1.7/*
   CO  BACKGRD PPM                           2
   CO2 SAMPLE  METER READING/SCALE          56.3/3
   CO2 SAMPLE  PERCENT                       .99
   CO2 BACKGRD METER READING/SCALE           2.6/3
   CO2 BACKGRD PERCENT                       .04
   NOX SAMPLE  METER READING/SCALE          64.6/2
   NOX SAMPLE  PPM                          64.6
   NOX BACKGRD METER READING/SCALE            .5/2
   NOX BACKGRD PPM                            .5
   HC  CONCENTRATION PPM                     6
   CO  CONCENTRATION PPM                    11
   CO2 CONCENTRATION PCT                    .95
   NOX CONCENTRATION PPM                  64.1
   SO2 COCENTRATION PPM                   0.0
   HC  MASS (GRAMS)                         .72
   CO  MASS (GRAMS)                        2.86
   CO2 MASS (GRAMS)                     3763.02
   NOX MASS (GRAMS)                       22.12
   SO2 MASS (GRAMS)                        0.00

HC  GRAMS/KILOMETRE       .03
CO  GRAMS/KILOMETRE       .13
CO2 GRAMS/KILOMETRE   173
NOX GRAMS/KILOMETRE      1.02
SO2 GRAMS/KILOMETRE      0.00

HC  GRAMS/KG OF FUEL    .61     HC  GRAMS/MIN    .03
CO  GRAMS/KG OF FUEL    2.4     CO  GRAMS/MIN     .1
CO2 GRAMS/KG OF FUEL   3164     CO2 GRAMS/MIN    162
NOX GRAMS/KG OF FUEL  18.60     NOX GRAMS/MIN    .95
SO2 GRAMS/KG OF FUEL   0.00     SO2 GRAMS/MIN   0.00
CARBON BALANCE FUEL ECONOMY =    7.41 LITRES PER HUNDRED KILOMETERS
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      TABLE  E-62  EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                           VEHICLE NUMBER 650

DATE 12/29/76              TIME    -0 HRS.         TEST NO. 1
MODEL  1977 VW GAS RABBIT  FET                     ENGINE 1.6 LITRE  4
DRIVER   DT                TEST WT.  1020 KG.      GVW    0 KG
WET BULB TEMP  14 C        DRY BULB TEMP  26 C     REL. HUM.  27.7 PCT
SPEC. HUM.   5.8 GRAM/KG   BARO.  741.7 MM  HG.    MEASURED FUEL  0.00 KG

 RUN DURATION          12.76 MINUTES
 BLOWER INLET PRESS. 602.0  MM. H2O
 BLOWER DIF.  PRESS. 602.0  MM  H2O
 BLOWER INLET TEMP.     41  DEG. C
 DYNO REVOLUTIONS       -0
 BLOWER REVOLUTIONS    61597
 BLOWER CU. CM /REV.  2235

 BAG RESULTS
  HC  SAMPLE  METER READING/SCALE          33.8/2
  HC  SAMPLE  PPM                           34
  HC  BACKGRD METER READING/SCALE          30.0/2
  HC  BACKGRD PPM                           30
  CO  SAMPLE  METER READING/SCALE           7.7/*
  CO  SAMPLE  PPM                            7
  CO  BACKGRD METER READING/SCALE           5.8/*
  CO  BACKGRD PPM                            6
  CO2 SAMPLE  METER READING/SCALE          66.7/3
  CO2 SAMPLE  PERCENT                      1.20
  CO2 BACKGRD METER READING/SCALE           3.7/3
  CO2 BACKGRD PERCENT                       .06
  NOX SAMPLE  METER READING/SCALE          34.0/3
  NOX SAMPLE  PPM                         102.0
  NOX BACKGRD METER READING/SCALE            .2/3
  NOX BACKGRD PPM                            .6
  HC  CONCENTRATION PPM                      6
  CO  CONCENTRATION PPM                      2
  CO2 CONCENTRATION PCT                    1.15
  NOX CONCENTRATION PPM                   101.5
  SO2 COCENTRATION PPM                     0.0
  HC  MASS (GRAMS)                          .44
  CO  MASS (GRAMS)                          .29
  CO2 MASS (GRAMS)                       2478.43
  NOX MASS (GRAMS)                         19.63
  SO2 MASS (GRAMS)                          0.00

HC  GRAMS/KILOMETRE       .03
CO  GRAMS/KILOMETRE       .02
CO2 GRAMS/KILOMETRE   150
NOX GRAMS/KILOMETRE      1.19
SO2 GRAMS/KILOMETRE      0.00

HC  GRAMS/KG OF FUEL     .56     HC  GRAMS/MIN     .03
CO  GRAMS/KG OF FUEL      .4     CO  GRAMS/MIN      .0
CO2 GRAMS/KG OF FUEL    3167     CO2 GRAMS/MIN    194
NOX GRAMS/KG OF FUEL   25.08     NOX GRAMS/MIN   1.54
SO2 GRAMS/KG OF FUEL    0.00     SO2 GRAMS/MIN   0.00
CARBON BALANCE FUEL ECONOMY =    6.43 LITRES PER HUNDRED KILOMETERS
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                    TABLE  E-63           VEHICLE EMISSION RESULTS
                                     1975  LIGHT DUTY EMISSIONS TEST
UNIT NO.  650        TEST NO. 2   75 FTP   DATE 12/30/76                  MFGR. CODE    -0                YR.  1977
VEHICLE MODEL   VW GAS RABBIT              ENGINE   1.59 LITRE 4          CURB WT.      0 KG              GVM     0 KG

BAROMETER 735.33 MM OF HG.                                            WET BULB TEMP  16.7 DEG. C
DRY BULB TEMP.   23.9 DEG. C                                           ABS. HUMIDITY   9.1 GRAMS/KG
REL. HUMIDITY     48 PCT.

EXHAUST EMISSIONS
                                                                      BLOWER INLET PRESS., G1 660.4 MM. H2O
     BLOWER DIF. PRESS., G2, 660.4 MM. H2O                            BLOWER INLET TEMP.   42 DEG. C
     BAG RESULTS
     BAG NO.                                     1              2              3
     BLOWER REVOLUTIONS                      40589          66845          40602
     HC   SAMPLE  METER READING/SCALE         67.3/2         21.5/2         24.0/2
     HC   SAMPLE  PPM                         67             21             24
     HC   BACKGRD METER READING/SCALE         14.5/2         16.1/2         15.9/2
     HC   BACKGRD PPM                         14             16             16
     CO   SAMPLE  METER READING/SCALE         91.8/*         78.8/*         67.8/*
     CO   SAMPLE  PPM                        458             78             66
     CO   BACKGRD METER READING/SCALE           .4/*           .1/*         1.0/*
     CO   BACKGRD PPM                           1              0              1
     CO2  SAMPLE  METER READING/SCALE         57.4/3         40.2/3         44.9/3
     CO2  SAMPLE  PERCENT                      1.01            .68            .77
     CO2  BACKGRD METER READING/SCALE          3.3/3          3.1/3          2.7/3
     CO2  BACKGRD PERCENT                       .05            .05            .04
     NOX  SAMPLE  METER READING/SCALE         43.1/2         11.8/2         30.2/2
     NOX  SAMPLE  PPM                         43.1           11.8           30.2
     NOX  BACKGRD METER READING/SCALE           .9/2           .7/2           .7/2
     NOX  BACKGRD PPM                           .9             .7             .7
     SO2  SAMPLE  METER READING/SCALE         -0.0/*         -0.0/*         -0.0/*
     SO2  SAMPLE  PPM                         -0.0           -0.0           -0.0
     SO2  BACKGRD METER READING/SCALE         -0.0/*         -0.0/*         -0.0/*
     SO2  BACKGRD PPM                         -0.0           -0.0           -0.0

     HC   CONCENTRATION PPM                   54              6              9
     CO   CONCENTRATION PPM                  441             75             63
     CO2  CONCENTRATION PCT                     .96            .64            .73
     NOX  CONCENTRATION PPM                   42.3           11.1           29.5
     SO2  CONCENTRATION PPM                    0.0            0.0            0.0
     HC   MASS GRAMS                           2.37            .45            .40
     CO   MASS GRAMS                          39.08          10.96           5.57
     CO2  MASS GRAMS                        1349.51        1462.69        1022.38
     NOX  MASS GRAMS                           5.84           2.53           4.09
     SO2  MASS GRAMS                           0.00           0.00           0.00

     WEIGHTED MASS HC        .14 GRAMS/KILOMETRE
     WEIGHTED MASS CO       2.56 GRAMS/KILOMETRE
     WEIGHTED MASS CO2    217.59 GRAMS/KILOMETRE
     WEIGHTED MASS NOX       .61 GRAMS/KILOMETRE
     WEIGHTED MASS SO2      0.00 GRAMS/KILOMETRE

   CARBON BALANCE FUEL CONSUMPTION =  9.47 LITRES PER HUNDRED KILOMETRES
   TOTAL CVS FLOW =   277.2 STD. CU. METRES
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TABLE E-64

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                                                   VEHICLE EMISSION RESULTS
                                              1975  LIGHT DUTY EMISSIONS TEST
UNIT NO.  650        TEST NO. 2  FTP Cold  DATE 12/30/76                    MFGR. CODE    -0              YR.  1977
VEHICLE MODEL   VW RABBIT GAS                ENGINE    1.59 LITRE 4           CURB WT.    884 KG              GVM      0 KG

                                                                           WET BULB TEMP  16.7 DEG. C
BAROMETER 735.33 MM OF HG.                                                  ABS. HUMIDITY    9.1 GRAMS/KG
DRY BULB TEMP.    23.9 DEG. C
REL. HUMIDITY      48 PCT.

EXHAUST EMISSIONS                                                          BLOWER INLET PRESS., G1 660.4 MM. H2O
                                                                           BLOWER INLET TEMP.    42 DEG. C
    BLOWER DIF. PRESS., G2, 660.4 MM. H2O
    BAG RESULTS
    BAG NO.                                             1              2              3
    BLOWER REVOLUTIONS                               40589          66845          40589
    HC    SAMPLE  METER READING/SCALE                 67.3/2         21.5/2         67.3/2
    HC    SAMPLE  PPM                                 67             21             67
    HC    BACKGRD METER READING/SCALE                 14.5/2         16.1/2         14.5/2
    HC    BACKGRD PPM                                 14             16             14
    CO    SAMPLE  METER READING/SCALE                 91.8/*         78.8/*         91.8/*
    CO    SAMPLE  PPM                                 458            78             458
    CO    BACKGRD METER READING/SCALE                 .4/*           .1/*           .4/*
    CO    BACKGRD PPM                                 1              0              1
    CO2   SAMPLE  METER READING/SCALE                 57.4/3         40.2/3         57.4/3
    CO2   SAMPLE  PERCENT                             1.01           .68            1.01
    CO2   BACKGRD METER READING/SCALE                 3.3/3          3.1/3          3.3/3
    CO2   BACKGRD PERCENT                             .05            .05            .05
    NOX   SAMPLE  METER READING/SCALE                 43.1/2         11.8/2         43.1/2
    NOX   SAMPLE  PPM                                 43.1           11.8           43.1
    NOX   BACKGRD METER READING/SCALE                 .9/2           .7/2           .9/2
    NOX   BACKGRD PPM                                 .9             .7             .9
    SO2   SAMPLE  METER READING/SCALE                 -0.0/*         -0.0/*         -0.0/*
    SO2   SAMPLE  PPM                                 -0.0           -0.0           -0.0
    SO2   BACKGRD METER READING/SCALE                 -0.0/*         -0.0/*         -0.0/*
    SO2   BACKGRD PPM                                 -0.0           -0.0           -0.0

    HC    CONCENTRATION PPM                           54             6              54
    CO    CONCENTRATION PPM                           441            75             441
    CO2   CONCENTRATION PCT                           .96            .64            .96
    NOX   CONCENTRATION PPM                           42.3           11.1           42.3
    SO2   CONCENTRATION PPM                           0.0            0.0            0.0
    HC    MASS GRAMS                                  2.37           .45            2.37
    CO    MASS GRAMS                                  39.08          10.96          39.08
    CO2   MASS GRAMS                                1349.51        1462.69        1349.51
    NOX   MASS GRAMS                                  5.84           2.53           5.84
    SO2   MASS GRAMS                                  0.00           0.00           0.00

    WEIGHTED MASS HC        .23 GRAMS/KILOMETRE
    WEIGHTED MASS CO       4.15 GRAMS/KILOMETRE
    WEIGHTED MASS CO2    233.04 GRAMS/KILOMETRE
    WEIGHTED MASS NOX       .69 GRAMS/KILOMETRE
    WEIGHTED MASS SO2      0.00 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION = 10.24 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =    277.1 STD. CU. METRES
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                    TABLE  E-65          VEHICLE EMISSION RESULTS
                                    1975  LIGHT DUTY EMISSIONS TEST
UNIT NO.  650       TEST NO. 2  FTP Hot  DATE 12/30/76              MFGR. CODE   -0               YR.  1977
VEHICLE MODEL  VW RABBIT GAS             ENGINE   1.59 LITRE 4      CURB WT.   884 KG             GVM     0 KG

BAROMETER 735.33 MM OF HG.                                    WET BULB TEMP  16.7 DEG. C
DRY BULB TEMP.    24.4 DEG. C                                  ABS. HUMIDITY   8.9 GRAMS/KG
REL. HUMIDITY      45 PCT.

EXHAUST EMISSIONS                                             BLOWER INLET PRESS., G1 673.1 MM. H2O
                                                              BLOWER INLET TEMP.    42 DEG. C
   BLOWER DIF. PRESS., G2, 673.1 MM. H2O
   BAG RESULTS
   BAG NO.                                    1            2            3
   BLOWER REVOLUTIONS                     40602        69610        40602
   HC   SAMPLE  METER READING/SCALE      24.0/2       25.9/2       24.0/2
   HC   SAMPLE  PPM                          24           26           24
   HC   BACKGRD METER READING/SCALE      15.9/2       19.3/2       15.9/2
   HC   BACKGRD PPM                          16           19           16
   CO   SAMPLE  METER READING/SCALE      67.8/*       83.2/*       67.8/*
   CO   SAMPLE  PPM                          66           83           66
   CO   BACKGRD METER READING/SCALE       1.0/*         .4/*        1.0/*
   CO   BACKGRD PPM                           1            0            1
   CO2  SAMPLE  METER READING/SCALE      44.9/3       39.2/3       44.9/3
   CO2  SAMPLE  PERCENT                     .77          .66          .77
   CO2  BACKGRD METER READING/SCALE       2.7/3        3.4/3        2.7/3
   CO2  BACKGRD PERCENT                     .04          .05          .04
   NOX  SAMPLE  METER READING/SCALE      30.2/2       11.4/2       30.2/2
   NOX  SAMPLE  PPM                        30.2         11.4         30.2
   NOX  BACKGRD METER READING/SCALE        .7/2         .5/2         .7/2
   NOX  BACKGRD PPM                          .7           .5           .7
   SO2  SAMPLE  METER READING/SCALE      -0.0/*       -0.0/*       -0.0/*
   SO2  SAMPLE  PPM                        -0.0         -0.0         -0.0
   SO2  BACKGRD METER READING/SCALE      -0.0/*       -0.0/*       -0.0/*
   SO2  BACKGRD PPM                        -0.0         -0.0         -0.0

   HC   CONCENTRATION PPM                     9            8            9
   CO   CONCENTRATION PPM                    63           80           63
   CO2  CONCENTRATION PCT                   .73          .61          .73
   NOX  CONCENTRATION PPM                  29.5         10.9         29.5
   SO2  CONCENTRATION PPM                   0.0          0.0          0.0
   HC   MASS GRAMS                          .40          .57          .40
   CO   MASS GRAMS                         5.57        12.14         5.57
   CO2  MASS GRAMS                      1020.47      1468.48      1020.47
   NOX  MASS GRAMS                         4.05         2.57         4.05
   SO2  MASS GRAMS                         0.00         0.00         0.00

   WEIGHTED MASS HC       .08 GRAMS/KILOMETRE
   WEIGHTED MASS CO      1.47 GRAMS/KILOMETRE
   WEIGHTED MASS CO2   206.25 GRAMS/KILOMETRE
   WEIGHTED MASS NOX      .55 GRAMS/KILOMETRE
   WEIGHTED MASS SO2     0.00 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION =  8.90 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =   282.1 STD. CU. METRES
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      TABLE  E-66   EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                         VEHICLE NUMBER 650

DATE 12/30/76               TIME     -0 HRS.          TEST NO. 2
MODEL  1977 VW RABBIT GAS   SET-7                     ENGINE 1.6 LITREI 4
DRIVER   DT                 TEST WT.  1020 KG.        GVW    0 KG
WET BULB TEMP  17 C         DRY BULB TEMP  26 C       REL. HUM.  40.0 PCT
SPEC. HUM.   8.4 GRAM/KG    BARO.  736.1 MM  HG.      MEASURED FUEL  0.00 KG

  RUN DURATION           23.30 MINUTES
  BLOWER INLET PRESS. 665.5  MM. H2O
  BLOWER DIF.  PRESS. 668.0  MM  H2O
  BLOWER INLET TEMP.     41  DEG. C
  DYNO REVOLUTIONS    31536
  BLOWER REVOLUTIONS   112376
  BLOWER CU. CM /REV.  2229

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE                 29.7/2
   HC   SAMPLE  PPM                                   30
   HC   BACKGRD METER READING/SCALE                 25.7/2
   HC   BACKGRD PPM                                   26
   CO   SAMPLE  METER READING/SCALE                 28.7/*
   CO   SAMPLE  PPM                                   27
   CO   BACKGRD METER READING/SCALE                   .2/*
   CO   BACKGRD PPM                                    0
   CO2  SAMPLE  METER READING/SCALE                 57.5/3
   CO2  SAMPLE  PERCENT                             1.01
   CO2  BACKGRD METER READING/SCALE                  2.8/3
   CO2  BACKGRD PERCENT                              .04
   NOX  SAMPLE  METER READING/SCALE                 60.3/2
   NOX  SAMPLE  PPM                                 60.3
   NOX  BACKGRD METER READING/SCALE                  .5/2
   NOX  BACKGRD PPM                                   .5
   HC   CONCENTRATION PPM                              6
   CO   CONCENTRATION PPM                             26
   CO2  CONCENTRATION PCT                            .97
   NOX  CONCENTRATION PPM                           59.8
   SO2  COCENTRATION PPM                            0.0
   HC   MASS (GRAMS)                                 .72
   CO   MASS (GRAMS)                                6.32
   CO2  MASS (GRAMS)                             3776.15
   NOX  MASS (GRAMS)                               22.43
   SO2  MASS (GRAMS)                                0.00

 HC   GRAMS/KILOMETRE       .03
 CO   GRAMS/KILOMETRE       .29
 CO2  GRAMS/KILOMETRE    174
 NOX  GRAMS/KILOMETRE      1.03
 SO2  GRAMS/KILOMETRE      0.00

 HC   GRAMS/KG OF FUEL     .61     HC   GRAMS/MIN     .03
 CO   GRAMS/KG OF FUEL     5.3     CO   GRAMS/MIN      .3
 CO2  GRAMS/KG OF FUEL    3159     CO2  GRAMS/MIN     162
 NOX  GRAMS/KG OF FUEL   18.76     NOX  GRAMS/MIN     .96
 SO2  GRAMS/KG OF FUEL    0.00     SO2  GRAMS/MIN    0.00
 CARBON BALANCE FUEL ECONOMY =     7.45 LITRES PER HUNDRED KILOMETERS
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      TABLE E-67    EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                          VEHICLE NUMBER 650

DATE 12/30/76               TIME     -0 HRS.          TEST NO. 2
MODEL  1977 VW RABBIT GAS   FET                       ENGINE 1.6 LITREI 4
DRIVER   DT                 TEST WT.  1020 KG.        GVW    0 KG
WET BULB TEMP  18 C         DRY BULB TEMP  26 C       REL. HUM.  46.5 PCT
SPEC. HUM.    9.8 GRAM/KG   BARO.  735.8 MM  HG.      MEASURED FUEL  0.00 KG

  RUN DURATION          12.76 MINUTES
  BLOWER INLET PRESS. 673.1  MM. H2O
  BLOWER DIF.  PRESS. 673.1  MM  H2O
  BLOWER INLET TEMP.     42  DEG. C
  DYNO REVOLUTIONS    23986
  BLOWER REVOLUTIONS    61572
  BLOWER CU. CM /REV.  2230

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE           38.6/2
   HC  SAMPLE  PPM                             39
   HC  BACKGRD METER READING/SCALE           35.3/2
   HC  BACKGRD PPM                             35
   CO  SAMPLE  METER READING/SCALE            6.3/*
   CO  SAMPLE  PPM                              6
   CO  BACKGRD METER READING/SCALE             .2/*
   CO  BACKGRD PPM                              0
   CO2 SAMPLE  METER READING/SCALE           68.5/3
   CO2 SAMPLE  PERCENT                       1.23
   CO2 BACKGRD METER READING/SCALE            3.3/3
   CO2 BACKGRD PERCENT                        .05
   NOX SAMPLE  METER READING/SCALE           96.4/2
   NOX SAMPLE  PPM                           96.4
   NOX BACKGRD METER READING/SCALE             .6/2
   NOX BACKGRD PPM                              .6
   HC  CONCENTRATION PPM                        7
   CO  CONCENTRATION PPM                        6
   CO2 CONCENTRATION PCT                     1.19
   NOX CONCENTRATION PPM                     95.9
   SO2 COCENTRATION PPM                      0.0
   HC  MASS (GRAMS)                           .44
   CO  MASS (GRAMS)                           .76
   CO2 MASS (GRAMS)                       2517.44
   NOX MASS (GRAMS)                         20.50
   SO2 MASS (GRAMS)                          0.00

HC  GRAMS/KILOMETRE       .03
CO  GRAMS/KILOMETRE       .05
CO2 GRAMS/KILOMETRE    153
NOX GRAMS/KILOMETRE      1.24
SO2 GRAMS/KILOMETRE      0.00

HC  GRAMS/KG OF FUEL     .55     HC  GRAMS/MIN    .03
CO  GRAMS/KG OF FUEL     1.0     CO  GRAMS/MIN     .1
CO2 GRAMS/KG OF FUEL    3166     CO2 GRAMS/MIN    197
NOX GRAMS/KG OF FUEL   25.78     NOX GRAMS/MIN   1.61
SO2 GRAMS/KG OF FUEL    0.00     SO2 GRAMS/MIN   0.00
CARBON BALANCE FUEL ECONOMY =     6.54 LITRES PER HUNDRED KILOMETERS
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                      TABLE  E-68            VEHICLE EMISSION RESULTS
                                         1975  LIGHT DUTY EMISSIONS TEST
UNIT NO.  650        TEST NO. 3  75 FTP    DATE  1/ 3/77                     MFGR. CODE   -0                  YR.  1977
VEHICLE MODEL  VW RABBIT GAS               ENGINE   1.59 LITRE 4             CURB WT.    884 KG               GVM      0 KG

BAROMETER 742.95 MM OF HG.                                              WET BULB TEMP  15.6 DEG  C
DRY BULB TEMP.    25.0 DEG. C                                            ABS. HUMIDITY    7.2 GRAMS/KG
REL. HUMIDITY      36 PCT.

EXHAUST EMISSIONS                                                       BLOWER INLET PRESS., G1 673.1 MM. H2O
                                                                        BLOWER INLET TEMP.    41 DEG. C
     BLOWER DIF. PRESS., G2, 673.1 MM. H2O
     BAG RESULTS
     BAG NO.                                         1                 2                 3
     BLOWER REVOLUTIONS                            40646             69510             40645
     HC    SAMPLE  METER READING/SCALE             25.1/2            18.2/2            49.7/2
     HC    SAMPLE  PPM                               25                18                50
     HC    BACKGRD METER READING/SCALE             11.9/2            12.8/2            11.5/2
     HC    BACKGRD PPM                               12                13                11
     CO    SAMPLE  METER READING/SCALE             64.0/*            59.5/*            78.2/*
     CO    SAMPLE  PPM                               62                57               351
     CO    BACKGRD METER READING/SCALE              1.1/*              .6/*              .7/*
     CO    BACKGRD PPM                                1                 1                 2
     CO2   SAMPLE  METER READING/SCALE             50.0/3            38.1/3            53.0/3
     CO2   SAMPLE  PERCENT                           .87               .64               .93
     CO2   BACKGRD METER READING/SCALE              3.1/3             3.4/3             3.4/3
     CO2   BACKGRD PERCENT                           .05               .05               .05
     NOX   SAMPLE  METER READING/SCALE             38.1/2            12.4/2            40.6/2
     NOX   SAMPLE  PPM                             38.1              12.4              40.6
     NOX   BACKGRD METER READING/SCALE               .4/2              .4/2              .6/2
     NOX   BACKGRD PPM                               .4                .4                .6
     SO2   SAMPLE  METER READING/SCALE            -0.0/*            -0.0/*            -0.0/*
     SO2   SAMPLE  PPM                            -0.0              -0.0              -0.0
     SO2   BACKGRD METER READING/SCALE            -0.0/*            -0.0/*            -0.0/*
     SO2   BACKGRD PPM                            -0.0              -0.0              -0.0

     HC    CONCENTRATION PPM                         14                 6                39
     CO    CONCENTRATION PPM                         59                55               339
     CO2   CONCENTRATION PCT                        .82               .59               .88
     NOX   CONCENTRATION PPM                       37.7              12.0              40.0
     SO2   CONCENTRATION PPM                        0.0               0.0               0.0
     HC    MASS GRAMS                               .62               .46              1.73
     CO    MASS GRAMS                              5.29              8.44             30.34
     CO2   MASS GRAMS                           1164.48           1435.10           1241.09
     NOX   MASS GRAMS                              4.98              2.71              5.29
     SO2   MASS GRAMS                              0.00              0.00              0.00

     WEIGHTED MASS HC        .14 GRAMS/KILOMETRE
     WEIGHTED MASS CO       2.32 GRAMS/KILOMETRE
     WEIGHTED MASS CO2    219.04 GRAMS/KILOMETRE
     WEIGHTED MASS NOX       .65 GRAMS/KILOMETRE
     WEIGHTED MASS SO2      0.00 GRAMS/KILOMETRE

    CARBON BALANCE FUEL CONSUMPTION =  9.51 LITRES PER HUNDRED KILOMETRES
    TOTAL CVS FLOW =    285.6 STD. CU. METRES
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                          TABLE E-69              VEHICLE EMISSION RESULTS
                                             1975  LIGHT DUTY EMISSIONS TEST
UNIT NO.  650        TEST NO.  3  FTP Cold DATE  1/ 3/77                    MFGR. CODE   -0               YR.  1977
VEHICLE MODEL  VW RABBIT GAS               ENGINE    1.59 LITRE 4           CURB WT.    884 KG            GVM      0 KG

BAROMETER 742.95 MM OF HG.                                           WET BULB TEMP  15.6 DEG. C
DRY BULB TEMP.   25.0 DEG. C                                          ABS. HUMIDITY   7.2 GRAMS/KG
REL. HUMIDITY     36 PCT.

EXHAUST EMISSIONS
                                                                     BLOWER INLET PRESS., G1 673.1 MM. H2O
     BLOWER DIF. PRESS., G2, 673.1 MM. H2O                           BLOWER INLET TEMP.    41 DEG. C
     BAG RESULTS
     BAG NO.                                        1            2            3
     BLOWER REVOLUTIONS                           40646        69510        40646
     HC    SAMPLE  METER READING/SCALE             25.1/2       18.2/2       25.1/2
     HC    SAMPLE  PPM                             25           18           25
     HC    BACKGRD METER READING/SCALE             11.9/2       12.8/2       11.9/2
     HC    BACKGRD PPM                             12           13           12
     CO    SAMPLE  METER READING/SCALE             64.0/*       59.5/*       64.0/*
     CO    SAMPLE  PPM                             62           57           62
     CO    BACKGRD METER READING/SCALE             1.1/*         .6/*        1.1/*
     CO    BACKGRD PPM                              1            1            1
     CO2   SAMPLE  METER READING/SCALE             50.0/3       38.1/3       50.0/3
     CO2   SAMPLE  PERCENT                          .87          .64          .87
     CO2   BACKGRD METER READING/SCALE             3.1/3        3.4/3        3.1/3
     CO2   BACKGRD PERCENT                          .05          .05          .05
     NOX   SAMPLE  METER READING/SCALE             38.1/2       12.4/2       38.1/2
     NOX   SAMPLE  PPM                             38.1         12.4         38.1
     NOX   BACKGRD METER READING/SCALE              .4/2         .4/2         .4/2
     NOX   BACKGRD PPM                              .4           .4           .4
     SO2   SAMPLE  METER READING/SCALE             -0.0/*       -0.0/*       -0.0/*
     SO2   SAMPLE  PPM                             -0.0         -0.0         -0.0
     SO2   BACKGRD METER READING/SCALE             -0.0/*       -0.0/*       -0.0/*
     SO2   BACKGRD PPM                             -0.0         -0.0         -0.0

     HC    CONCENTRATION PPM                        14            6           14
     CO    CONCENTRATION PPM                        59           55           59
     CO2   CONCENTRATION PCT                        .82          .59          .82
     NOX   CONCENTRATION PPM                       37.7         12.0         37.7
     SO2   CONCENTRATION PPM                        0.0          0.0          0.0
     HC    MASS GRAMS                               .62          .46          .62
     CO    MASS GRAMS                              5.29         8.44         5.29
     CO2   MASS GRAMS                           1164.48      1435.10      1164.48
     NOX   MASS GRAMS                              4.98         2.71         4.98
     SO2   MASS GRAMS                              0.00         0.00         0.00

     WEIGHTED MASS HC         .09 GRAMS/KILOMETRE
     WEIGHTED MASS CO        1.14 GRAMS/KILOMETRE
     WEIGHTED MASS CO2     215.42 GRAMS/KILOMETRE
     WEIGHTED MASS NOX        .64 GRAMS/KILOMETRE
     WEIGHTED MASS SO2       0.00 GRAMS/KILOMETRE

   CARBON BALANCE FUEL CONSUMPTION =  9.27 LITRES PER HUNDRED KILOMETRES
   TOTAL CVS FLOW =    285.6 STD. CU. METRES
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                    TABLE  E-70             VEHICLE EMISSION RESULTS
                                       1975  LIGHT DUTY EMISSIONS TEST
                                                                MFGR. CODE   -0                YR.  1977
UNIT NO.  650        TEST NO. 3  FTP Hot   DATE  1/ 3/77                CURB WT.   884 KG                GVM      0 KG
VEHICLE MODEL  VW RABBIT GAS               ENGINE   1.59 LITRE 4

                                                                WET BULB TEMP  14.4 DEG. C
BAROMETER 742.95 MM OF HG.                                      ABS. HUMIDITY   6.2 GRAMS/KG
DRY BULB TEMP.    24.4 DEG. C
REL. HUMIDITY      32 PCT.

EXHAUST EMISSIONS                                               BLOWER INLET PRESS., G1 665.5 MM. H2O
                                                                BLOWER INLET TEMP.    41 DEG. C
    BLOWER DIF. PRESS., G2, 665.5 MM. H2O
    BAG RESULTS
    BAG NO.                                      1              2              3
    BLOWER REVOLUTIONS                       40645          69783          40645
    HC   SAMPLE  METER READING/SCALE        49.7/2         17.9/2         49.7/2
    HC   SAMPLE  PPM                           50             18             50
    HC   BACKGRD METER READING/SCALE        11.5/2         12.0/2         11.5/2
    HC   BACKGRD PPM                           11             12             11
    CO   SAMPLE  METER READING/SCALE        78.2/*         70.9/*         78.2/*
    CO   SAMPLE  PPM                          351             69            351
    CO   BACKGRD METER READING/SCALE          .7/*           .7/*           .7/*
    CO   BACKGRD PPM                            2              2              2
    CO2  SAMPLE  METER READING/SCALE        53.0/3         38.9/3         53.0/3
    CO2  SAMPLE  PERCENT                      .93            .66            .93
    CO2  BACKGRD METER READING/SCALE         3.4/3          2.6/3          3.4/3
    CO2  BACKGRD PERCENT                      .05            .04            .05
    NOX  SAMPLE  METER READING/SCALE        40.6/2         12.4/2         40.6/2
    NOX  SAMPLE  PPM                         40.6           12.4           40.6
    NOX  BACKGRD METER READING/SCALE          .6/2           .4/2           .6/2
    NOX  BACKGRD PPM                           .6             .4             .6
    SO2  SAMPLE  METER READING/SCALE        -0.0/*         -0.0/*         -0.0/*
    SO2  SAMPLE  PPM                         -0.0           -0.0           -0.0
    SO2  BACKGRD METER READING/SCALE        -0.0/*         -0.0/*         -0.0/*
    SO2  BACKGRD PPM                         -0.0           -0.0           -0.0

    HC   CONCENTRATION PPM                     39              6             39
    CO   CONCENTRATION PPM                    339             66            339
    CO2  CONCENTRATION PCT                    .88            .62            .88
    NOX  CONCENTRATION PPM                   40.0           12.0           40.0
    SO2  CONCENTRATION PPM                    0.0            0.0            0.0
    HC   MASS GRAMS                          1.73            .50           1.73
    CO   MASS GRAMS                         30.41          10.11          30.41
    CO2  MASS GRAMS                       1242.47        1507.27        1242.47
    NOX  MASS GRAMS                          5.14           2.65           5.14
    SO2  MASS GRAMS                          0.00           0.00           0.00

    WEIGHTED MASS HC       .18 GRAMS/KILOMETRE
    WEIGHTED MASS CO      3.36 GRAMS/KILOMETRE
    WEIGHTED MASS CO2   227.86 GRAMS/KILOMETRE
    WEIGHTED MASS NOX      .65 GRAMS/KILOMETRE
    WEIGHTED MASS SO2     0.00 GRAMS/KILOMETRE

  CARBON BALANCE FUEL CONSUMPTION =  9.96 LITRES PER HUNDRED KILOMETRES
  TOTAL CVS FLOW =    286.4 STD. CU. METRES
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        TABLE  E-71    EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                              VEHICLE NUMBER 650

DATE  1/ 3/77              TIME     -0 HRS.          TEST NO. 3
MODEL  1977 VW RABBIT GAS  SET-7                     ENGINE 1.6 LITRE  4
DRIVER   DT                TEST WT.  1020 KG.        GVW    0 KG
WET BULB TEMP  14 C        DRY BULB TEMP  24 C       REL. HUM.  28.9 PCT
SPEC. HUM.    5.6 GRAM/KG  BARO.  743.2 MM  HG.      MEASURED FUEL  0.00 KG

  RUN DURATION          23.30 MINUTES
  BLOWER INLET PRESS. 673.1  MM. H2O
  BLOWER DIF.  PRESS. 673.1  MM  H2O
  BLOWER INLET TEMP.     41  DEG. C
  DYNO REVOLUTIONS     31269
  BLOWER REVOLUTIONS   112400
  BLOWER CU. CM /REV.  2227

  BAG RESULTS
   HC   SAMPLE  METER READING/SCALE          17.7/2
   HC   SAMPLE  PPM                            18
   HC   BACKGRD METER READING/SCALE          15.2/2
   HC   BACKGRD PPM                            15
   CO   SAMPLE  METER READING/SCALE          14.7/*
   CO   SAMPLE  PPM                            14
   CO   BACKGRD METER READING/SCALE           1.6/*
   CO   BACKGRD PPM                             2
   CO2  SAMPLE  METER READING/SCALE          57.1/3
   CO2  SAMPLE  PERCENT                      1.01
   CO2  BACKGRD METER READING/SCALE           3.1/3
   CO2  BACKGRD PERCENT                       .05
   NOX  SAMPLE  METER READING/SCALE          61.5/2
   NOX  SAMPLE  PPM                          61.5
   NOX  BACKGRD METER READING/SCALE           .7/2
   NOX  BACKGRD PPM                            .7
   HC   CONCENTRATION PPM                       4
   CO   CONCENTRATION PPM                      12
   CO2  CONCENTRATION PCT                     .96
   NOX  CONCENTRATION PPM                    60.9
   SO2  COCENTRATION PPM                     0.0
   HC   MASS (GRAMS)                          .45
   CO   MASS (GRAMS)                         2.99
   CO2  MASS (GRAMS)                      3769.30
   NOX  MASS (GRAMS)                        21.23
   SO2  MASS (GRAMS)                         0.00

HC   GRAMS/KILOMETRE      .02
CO   GRAMS/KILOMETRE      .14
CO2  GRAMS/KILOMETRE   173
NOX  GRAMS/KILOMETRE      .98
SO2  GRAMS/KILOMETRE     0.00

HC   GRAMS/KG OF FUEL     .38     HC   GRAMS/MIN     .02
CO   GRAMS/KG OF FUEL     2.5     CO   GRAMS/MIN      .1
CO2  GRAMS/KG OF FUEL    3164     CO2  GRAMS/MIN     162
NOX  GRAMS/KG OF FUEL   17.83     NOX  GRAMS/MIN     .91
SO2  GRAMS/KG OF FUEL    0.00     SO2  GRAMS/MIN    0.00
CARBON BALANCE FUEL ECONOMY =    7.42 LITRES PER HUNDRED KILOMETERS
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      ABLE  E-72   EXHAUST EMISSIONS FROM SINGLE BAG SAMPLE
                          VEHICLE NUMBER 650

DATE  1/ 3/77                 TIME     -0 HRS.        TEST NO. 3
MODEL  1977 VW RABBIT GAS     FET                     ENGINE 1.6 LITRE  4
DRIVER   DT                   TEST WT.  1020 KG.      GVW    0 KG
WET BULB TEMP  19 C           DRY BULB TEMP  25 C     REL. HUM.  29.8 PCT
SPEC. HUM.    6.0 GRAM/KG     BARO.  743.2 MM  HG.    MEASURED FUEL  0.00 KG

  RUN DURATION          12.76 MINUTES
  BLOWER INLET PRESS. 673.1  MM. H2O
  BLOWER DIF.  PRESS. 673.1  MM  H2O
  BLOWER INLET TEMP.     40  DEG. C
  DYNO REVOLUTIONS    23900
  BLOWER REVOLUTIONS    61525
  BLOWER CU. CM /REV.  2225

  BAG RESULTS
   HC  SAMPLE  METER READING/SCALE            23.3/2
   HC  SAMPLE  PPM                              23
   HC  BACKGRD METER READING/SCALE            19.5/2
   HC  BACKGRD PPM                              19
   CO  SAMPLE  METER READING/SCALE             4.8/*
   CO  SAMPLE  PPM                               5
   CO  BACKGRD METER READING/SCALE             1.7/*
   CO  BACKGRD PPM                               2
   CO2 SAMPLE  METER READING/SCALE            68.4/3
   CO2 SAMPLE  PERCENT                        1.23
   CO2 BACKGRD METER READING/SCALE             3.3/3
   CO2 BACKGRD PERCENT                         .05
   NOX SAMPLE  METER READING/SCALE            34.9/3
   NOX SAMPLE  PPM                           104.7
   NOX BACKGRD METER READING/SCALE              .3/3
   NOX BACKGRD PPM                              .9
   HC  CONCENTRATION PPM                         6
   CO  CONCENTRATION PPM                         3
   CO2 CONCENTRATION PCT                      1.19
   NOX CONCENTRATION PPM                     103.9
   SO2 CONCENTRATION PPM                      0.0
   HC  MASS (GRAMS)                            .38
   CO  MASS (GRAMS)                            .41
   CO2 MASS (GRAMS)                        2546.60
   NOX MASS (GRAMS)                          20.07
   SO2 MASS (GRAMS)                           0.00

 HC  GRAMS/KILOMETRE      .02
 CO  GRAMS/KILOMETRE      .02
 CO2 GRAMS/KILOMETRE   155
 NOX GRAMS/KILOMETRE     1.22
 SO2 GRAMS/KILOMETRE     0.00

 HC  GRAMS/KG OF FUEL    .47      HC  GRAMS/MIN     .03
 CO  GRAMS/KG OF FUEL    .5       CO  GRAMS/MIN     .0
 CO2 GRAMS/KG OF FUEL   3167      CO2 GRAMS/MIN    200
 NOX GRAMS/KG OF FUEL  24.96      NOX GRAMS/MIN    1.57
 SO2 GRAMS/KG OF FUEL   0.00      SO2 GRAMS/MIN    0.00
 CARBON BALANCE FUEL ECONOMY =    6.61 LITRES PER HUNDRED KILOMETERS
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APPENDIX F

UNREGULATED EMISSIONS
FOR
FOUR LD VEHICLES

TABLE F-1. SUMMARY OF EXHAUST SMOKE OPACITY RECORDED DURING 1975 FTP WITH TWO DIESEL POWERED CARS

	Olds Cutlass				VW Rabbit		
Smoke Condition	Run 1	Run 2	Run 3	Avg.	Run 1	Run 2	Avg.
Cold Start, Peak %	19.2	18.0	11.7	16.3	70.0	75.7	72.9
Cold Idle, Avg. % (after start)	4.2	5.5	3.5	4.4	6.0	3.0	4.5
1st Accel, Peak % (after cold idle)	23.8	21.5	18.8	21.4	7.8	7.0	7.4
Idle at 125 Sec. Avg.%	5.7	5.5	4.5	5.2	0.5	0.5	0.5
Accel at 164 Sec.Peak% to 90.1 km/hr (56 mph)	19.0	24.2	14.9	19.4	34.7	44.0	39.4
Hot Start, Peak %	8.8	6.7	----	7.8	28.0	26.8	27.4
Hot Idle, Avg. % (after start)	4.3	3.9	----	4.1	0.2	0.6	0.4
1st Accel, Peak % (after hot idle)	5.9	9.0	----	7.5	3.0	3.0	3.0
Idle at 125 Sec. Avg.% (during final 505 sec)	4.6	4.0	----	4.3	0.3	0.3	0.3
Accel at 164 Sec. Peak% to 90.1 km/hr (56 mph) (during final 505 sec)	17.0	16.2	----	16.6	34.3	41.0	37.7

TABLE F-2.SUMMARY OF EXHAUST SMOKE OPACITY RECORDED DURING SULFATE EMISSION TEST CYCLE WITH TWO DIESEL POWERED CARS

	Olds Cutlass			VW Rabbit		
Smoke Condition	Run 1	Run 2	Avg.	Run 1	Run 2	Avg.
Hot Start, Peak %	6.0	7.2	6.6	38.7	N.D.	38.7
Idle, Avg. % (after start)	3.8	3.9	3.9	0.1	0.3	0.2
1st Accel, Peak % to 26.1 km/hr	9.8	6.7	8.3	3.3	5.3	4.3
Accel at 189 sec, Peak % from 16.1 km/hr to 90.9 km/hr	15.0	13.4	15.2	6.0	5.3	5.7
Accel at 527 sec, Peak % from 0 km/hr to 57.1 km/hr	4.7	14.8	9.8	14.0	27.4	20.7
Accel at 638 sec, Peak % from 15.6 km/hr to 91.7 km/hr	11.3	11.3	11.3	6.3	4.5	5.4
Accel at 944 sec, Peak % from 22.5 km/hr to 90.9 km/hr	8.0	6.5	7.3	4.0	8.0	6.0

TABLE F-3.SUMMARY OF EXHAUST SMOKE OPACITY RECORDED DURING HIGHWAY FUEL ECONOMY TEST CYCLE WITH TWO DIESEL POWERED CARS

	Olds Cutlass			VW Rabbit		
Smoke Condition	Run 1	Run 2	Avg.	Run 1	Run 2	Avg.
Hot Start, Peak %	6.0	11.0	8.5	46.5	27.5	37.0
Idle, Avg.,% (after start)	4.0	4.0	4.0	0.4	0.3	0.4
1st Accel, Peak % to 79.6 km/hr	9.0	10.0	9.5	5.0	5.0	5.0
Accel, Peak % to 94.9 km/hr	9.8	13.0	11.4	5.2	6.5	5.9

TABLE F-4. PARTICULATE AND SULFATE EMISSION RATES
1977 OLDSMOBILE CUTLASS DIESEL

			Particulate Rate			Sulfate Rate			
Test	Date	Run	g/hr	g/kg fuel	g/km	mg/hr	mg(2)/kg fuel	mg/km	as % S in fuel
1975 FTP(1)	10/26/76	1	17.382	6.074	0.553	320.000	111.126	10.185	1.61
	10/27/76	2	17.272	6.042	0.550	306.005	106.118	9.739	1.54
	10/28/76	3	19.330	6.792	0.616	-------	-------	------	----
	Average		17.995	6.303	0.573	313.003	108.622	9.962	1.57
FTP_c	10/26/76	1	19.917	6.529	0.634	405.527	132.9	12.907	1.93
	10/27/76	2	19.559	6.406	0.622	397.880	130.4	12.664	1.89
	10/28/76	3	20.745	6.808	0.661	-------	-------	------	----
	Average		20.074	6.581	0.628	401.703	131.6	12.786	1.91
FTP_h	10/26/76	1	15.469	5.732	0.492	255.480	94.7	8.132	1.37
	10/27/76	2	15.546	5.767	0.495	236.697	87.8	7.533	1.27
	10/28/76	3	18.263	6.781	0.582	-------	-------	------	----
	Average		16.426	6.093	0.523	246.088	91.2	7.832	1.32
SET	10/26/76	1	20.089	4.848	0.359	576.544	90.0	10.301	1.30
	10/27/76	2	19.932	4.807	0.356	579.441	90.4	10.350	1.31
	10/28/76	3	20.453	4.929	0.365	-------	-------	------	----
	Average		20.158	4.861	0.360	577.992	90.2	10.326	1.30
FET	10/26/76	1	22.269	4.526	0.288	711.882	144.2	9.179	2.09
	10/27/76	2	24.386	4.935	0.314	612.880	124.2	7.903	1.80
	10/28/76	3	22.575	4.573	0.291	-------	-------	------	----
	Average		23.077	4.678	0.298	662.381	134.2	8.541	1.94

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(1) 1975 FTP = 0.43 FTP_c + 0.57 FTP_h

(2) Based on average fuel consumption

FTP_c = 11.46 ℓ/100 km
FTP_h = 10.13 ℓ/100 km
SET = 8.74 ℓ/100 km
FET = 7.51 ℓ/100 km

TABLE F-5.PARTICULATE AND SULFATE EMISSION RATES
1977 Oldsmobile Cutlass Gasoline

			Particulate Rates			Sulfate Rates			
Test	Date	Run	mg/hr	mg/kg fuel(2)	mg/km	mg/hr	mg/kg fuel(2)	mg/km	as % S in fuel
1975 FTP(1)	12/20/76	1	132.78	9.55	1.08	--	--	--	--
	12/21/76	2	197.76	57.43	6.43	34.038	10.081	1.065	1.416
	12/22/76	3	294.43	82.66	9.37	52.900	15.985	1.682	1.762
	Average		208.32	49.88	5.63	43.469	13.033	1.373	1.589
FTP Cold	12/20/76	1	51.84	14.04	1.65	--	--	--	--
	12/21/76	2	270.20	73.18	8.60	2.376	0.646	0.076	0.069
	12/22/76	3	468.14	126.78	14.90	2.577	0.697	0.082	0.075
	Average		263.39	71.33	8.38	2.476	0.672	0.079	0.072
FTP Hot	12/20/76	1	193.85	6.17	0.65	--	--	--	--
	12/21/76	2	143.14	45.56	4.80	57.907	17.200	1.812	1.849
	12/22/76	3	163.38	49.36	5.20	90.875	27.519	2.889	2.959
	Average		166.79	33.70	3.55	74.391	22.360	2.351	2.404
SET	12/20/76	1	330.30	67.56	5.90	--	--	--	--
	12/21/86	2	663.40	135.69	11.85	542.050	110.647	9.663	11.897
	12/22/76	3	638.20	130.54	11.40	913.911	186.930	16.325	20.100
	Average		543.97	111.26	9.72	727.980	148.789	12.994	15.999
FET	12/20/76	1	418.78	71.43	5.40	--	--	--	--
	12/21/76	2	523.48	89.29	6.75	1023.125	174.510	13.192	18.764
	12/22/76	3	2225.78	379.66	28.70	864.038	147.379	11.141	15.847
	Average		1056.01	181.13	13.62	943.582	160.944	12.167	17.306

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(1) 1975 FTP = 0.43 FTPc + 0.57 FTPh

(2) Based on average fuel consumption:
FTPc = 15.92 1/100 km
FTPh = 14.27 1/100 km
SET = 11.83 1/100 km
FET = 10.24 1/100 km

TABLE F-6.PARTICULATE AND SULFATE EMISSION RATES
1977 VW RABBIT DIESEL

			Particulate Rate			Sulfate Rate			
Test	Date	Run	g/hr	g(2)/kg fuel	g/km	mg/hr	mg(2)/kg fuel	mg/km	as % S in fuel
1975 FTP(1)	11/29/76	1	5.934	4.109	0.189	115.645	79.859	3.681	1.15
	11/30/76	2	5.707	3.932	0.186	114.833	79.076	3.644	1.33
	12/1/76	3	5.387	3.751	0.172	-------	-------	-----	----
	Average		5.676	3.930	0.182	115.239	79.468	3.662	1.24
FTP_c	11/29/76	1	6.284	4.192	0.200	137.884	92.0	4.388	1.33
	11/30/76	2	7.024	4.675	0.223	139.062	92.3	4.402	1.34
	12/1/76	3	5.747	3.836	0.183	-------	-------	-----	----
	Average		6.352	4.234	0.202	138.473	92.2	4.395	1.34
FTP_h	11/29/76	1	5.671	4.046	0.180	98.868	70.7	3.147	1.02
	11/30/76	2	4.714	3.372	0.150	96.555	69.1	3.073	1.00
	12/1/76	3	5.116	3.687	0.164	-------	-------	-----	----
	Average		5.167	3.702	0.165	97.712	69.9	3.110	1.02
SET	11/29/76	1	9.106	4.266	0.163	262.534	122.7	4.690	1.78
	11/30/76	2	9.210	4.082	0.156	225.837	105.6	4.034	1.53
	12/1/76	3	9.241	4.318	0.165	-------	-------	-----	----
	Average		9.186	4.222	0.161	244.186	114.2	4.362	1.66
FET	11/29/76	1	12.095	4.194	0.156	299.797	103.9	3.866	1.50
	11/30/76	2	11.923	4.140	0.154	307.309	106.5	3.962	1.54
	12/1/76	3	12.511	4.355	0.162	-------	-------	-----	----
	Average		12.176	4.230	0.157	303.553	105.2	3.914	1.52

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(1) 1975 FTP = 0.43 FTP_c + 0.57 FTP_h
(2) Based on average fuel consumption
FTP_c = 5.63 ℓ/100 km
FTP_h = 5.25 ℓ/100 km
FET = 4.51 ℓ/100 km
SET = 4.39 ℓ/100 km

TABLE F-7.PARTICULATE AND SULFATE EMISSION RATES
1977 VW Rabbit Gasoline

Test	Date	Run	Particulate Rates mg/hr	Particulate Rates mg/kg fuel[2]	Particulate Rates mg/km	Sulfate Rates mg/hr	Sulfate Rates mg/kg fuel[2]	Sulfate Rates mg/km	Sulfate Rates as % S in fuel
1975 FTP[1]	12/20/76	1	118.29	52.02	3.76	--	--	--	--
	12/21/76	2	--	--	-	0.70	0.318	0.022	0.034
	12/22/76	3	148.44	65.53	4.72	1.88	0.835	0.060	0.090
	Average		133.36	58.78	4.24	1.29	0.576	0.041	0.062
FTP Cold	12/20/76	1	182.23	79.28	5.80	--	--	--	--
	12/21/76	2	97.40	42.37	3.10	0.391	0.178	0.013	0.019
	12/22/76	3	186.94	81.33	5.95	1.408	0.615	0.045	0.066
	Average		155.52	67.66	4.95	0.900	0.396	0.029	0.043
FTP Hot	12/20/76	1	70.06	31.46	2.23	--	--	--	--
	12/21/76	2	--	--	--	0.937	0.423	0.030	0.045
	12/22/76	3	119.39	53.62	3.80	2.233	1.001	0.071	0.108
	Average		94.72	42.54	3.01	1.585	0.712	0.051	0.076
SET	12/20/76	1	83.97	27.35	1.50	--	--	--	--
	12/21/76	2	33.59	10.94	0.60	59.117	19.252	1.056	2.070
	12/22/76	3	97.97	31.90	1.75	55.561	18.086	0.992	1.947
	Average		71.84	23.40	1.28	57.339	18.669	1.024	2.009
FET	12/20/76	1	46.53	12.45	0.60	--	--	--	--
	12/21/76	2	--	--	--	217.685	58.229	2.807	6.261
	12/22/76	3	193.88	51.86	2.50	244.259	65.334	3.150	7.026
	Average		120.20	32.16	1.55	230.972	61.782	2.979	6.644

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(1) 1975 FTP = 0.43 FTPc + 0.57 FTPh

(2) Based on average fuel consumption:
FTPc = 9.91 l/100 km
FTPh = 9.60 l/100 km
SET = 7.43 l/100 km
FET = 6.53 l/100 km

TABLE F-8. COMPARISON OF ODOR PANEL RATINGS

VEHICLE: Oldsmobile Diesel Car

Operating Condition	Date	Dilution Ratio	"D" Composite	"B" Burnt	"O" Oily	"A" Aromatic	"P" Pungent
Inter Speed 0 Load	11/29/76	100:1	2.8	1.0	1.0	0.6	0.3
	12/01/76	100:1	2.2	1.0	0.9	0.5	0.3
	Average	100:1	2.5	1.0	1.0	0.6	0.3
	12/03/76	550:1	1.1	0.8	0.2	0.3	0
Inter Speed Mid Load	11/29/76	100:1	3.1	1.0	1.0	0.7	0.6
	12/01/76	100:1	2.3	1.0	0.9	0.3	0.5
	Average	100:1	2.7	1.0	1.0	0.5	0.6
	12/03/76	550:1	1.0	0.7	0.3	0.2	0.1
Inter Speed High Load	11/29/76	100:1	3.2	1.0	1.0	0.8	0.7
	12/01/76	100:1	2.3	1.0	0.9	0.4	0.4
	Average	100:1	2.8	1.0	1.0	0.6	0.6
	12/03/76	550:1	0.8	0.7	0.2	0.2	0
High Speed 0 Load	11/29/76	100:1	3.3	1.0	1.0	0.9	0.7
	12/01/76	100:1	2.6	1.0	0.9	0.6	0.7
	Average	100:1	3.0	1.0	1.0	0.8	0.7
	12/03/76	550:1	0.9	0.8	0.3	0.2	0
High Speed Mid Load	11/29/76	100:1	3.4	1.2	1.0	0.8	0.6
	12/01/76	100:1	2.9	1.0	1.0	0.4	0.8
	Average	100:1	3.2	1.1	1.0	0.6	0.7
	12/03/76	550:1	1.0	0.7	0.2	0.3	0
High Speed High Load	11/29/76	100:1	3.5	1.1	1.0	0.6	0.7
	12/01/76	100:1	3.1	1.0	1.0	0.7	0.7
	Average	100:1	3.3	1.1	1.0	0.7	0.7
	12/03/76	550:1	1.0	0.8	0.3	0.2	0.1
Idle	11/29/76	100:1	3.8	1.3	1.0	0.9	0.6
	12/01/76	100:1	2.9	1.0	1.0	0.6	0.6
	Average	100:1	3.4	1.2	1.0	0.8	0.6
	12/03/76	550:1	0.8	0.6	0.3	0.2	0
Idle-Accel	11/29/76	100:1	2.9	1.0	1.0	0.7	0.5
	12/01/76	100:1	2.3	1.0	0.8	0.6	0.5
	Average	100:1	2.6	1.0	0.9	0.7	0.5
	12/03/76	550:1	1.0	0.8	0.4	0.3	0.1
Acceleration	11/29/76	100:1	3.0	1.0	1.0	0.7	0.5
	12/01/76	100:1	2.6	1.0	1.0	0.6	0.5
	Average	100:1	2.8	1.0	1.0	0.7	0.5
	12/03/76	550:1	1.0	0.8	0.3	0.2	0
Deceleration	11/29/76	100:1	3.0	1.0	1.0	0.7	0.6
	12/01/76	100:1	2.5	1.0	1.0	0.5	0.5
	Average	100:1	2.8	1.0	1.0	0.6	0.6
	12/03/76	550:1	1.3	0.9	0.5	0.2	0.1
Cold Start	11/29/76	100:1	4.9	1.7	1.0	1.0	0.7
	12/01/76	100:1	3.1	1.0	0.9	0.7	0.9
	Average	100:1	4.0	1.4	1.0	0.9	0.8
	12/03/76	550:1	2.0	1.0	1.0	0.2	0.2

TABLE F-9. VEHICLE ODOR EVALUATION SUMMARY

Vehicle: Oldsmobile Diesel Car Dilution Ratio 100:1
Date: November 29, 1976

Run No.	Operating Condition	"D" Composite	"B" Burnt	"O" Oily	"A" Aromatic	"P" Pungent
9	Inter Speed	3.3	1.1	0.9	0.7	0.6
14	0 Load	2.6	1.0	1.0	0.6	0.1
19		2.6	1.0	1.0	0.6	0.3
		2.8	1.0	1.0	0.6	0.3
1	Inter Speed	4.1	1.0	1.0	0.9	1.0
8	Mid-Load	2.7	1.0	1.0	0.7	0.4
18		2.4	1.0	1.0	0.6	0.3
		3.1	1.0	1.0	0.7	0.6
5	Inter Speed	3.0	1.0	1.0	0.7	0.7
12	High Load	3.6	1.1	1.0	0.9	0.7
20		3.1	1.0	1.0	0.9	0.6
		3.2	1.0	1.0	0.8	0.7
3	High Speed	3.2	1.0	0.9	0.9	0.7
11	0 Load	3.2	1.0	1.0	0.9	0.7
21		3.4	1.0	1.0	1.0	0.6
		3.3	1.0	1.0	0.9	0.7
4	High Speed	4.3	1.6	1.0	0.9	1.0
13	Mid-Load	2.9	1.0	1.0	0.7	0.4
17		3.1	1.0	1.0	0.9	0.4
		3.4	1.2	1.0	0.8	0.6
7	High Speed	3.9	1.3	1.0	1.0	0.6
10	High Load	3.3	1.0	1.0	0.6	0.9
16		3.2	1.0	1.0	0.3	0.6
		3.5	1.1	1.0	0.6	0.7
2	Idle	4.0	1.3	1.0	1.0	0.7
6		3.4	1.3	0.9	0.9	0.6
15		3.9	1.3	1.0	0.7	0.6
		3.8	1.3	1.0	0.9	0.6
22	Idle-Accel	2.9	1.0	0.9	0.7	0.6
27		2.9	1.0	1.0	0.7	0.6
31.		2.6	1.0	1.0	0.6	0.4
33.		3.0	1.0	1.0	0.9	0.4
		2.9	1.0	1.0	0.7	0.5
23	Accel	2.9	1.0	1.0	0.6	0.7
26		3.0	1.0	1.0	0.7	0.6
29		3.1	1.0	1.0	0.7	0.4
32		2.9	1.0	1.0	0.7	0.4
		3.0	1.0	1.0	0.7	0.5
24	Decel	3.3	1.0	1.0	0.7	0.6
25		2.7	1.0	1.0	0.6	0.4
28		3.1	1.0	1.0	0.7	0.7
30		3.0	1.0	1.0	0.7	0.6
		3.0	1.0	1.0	0.7	0.6
	Cold Start	4.9	1.7	1.0	1.0	0.7

TABLE F-10. VEHICLE ODOR EVALUATION SUMMARY

Vehicle: Oldsmobile Diesel Car   Dilution Ratio: 100:1
Date: December 1, 1976

Run No.	Operating Condition	"D" Composite	"B" Burnt	"O" Oily	"A" Aromatic	"P" Pungent
3	Inter Speed 0 Load	2.2	1.0	0.9	0.4	0.3
8		2.3	1.0	0.9	0.6	0.3
13		2.1	1.0	0.9	0.4	0.3
		2.2	1.0	0.9	0.5	0.3
4	Inter Speed Mid-Load	2.2	1.0	0.9	0.4	0.6
14		2.3	0.9	1.0	0.3	0.4
21		2.4	1.0	0.9	0.3	0.6
		2.3	1.0	0.9	0.3	0.5
2	Inter Speed High Load	2.4	1.0	1.0	0.3	0.6
10		1.9	1.0	0.9	0.3	0.3
17		2.6	1.0	0.9	0.6	0.4
		2.3	1.0	0.9	0.4	0.4
1	High Speed 0 Load	2.6	1.0	0.9	0.4	0.7
11		2.4	0.9	0.7	0.7	0.6
19		2.7	1.0	1.0	0.6	0.7
		2.6	1.0	0.9	0.6	0.7
5	High Speed Mid-Load	3.0	1.0	1.0	0.3	1.0
9		3.0	1.0	1.0	0.6	0.7
18		2.7	1.0	1.0	0.4	0.6
		2.9	1.0	1.0	0.4	0.8
6	High Speed High Load	3.7	1.0	1.0	0.9	0.9
12		2.7	1.0	1.0	0.6	0.4
15		2.9	1.0	0.9	0.6	0.7
		3.1	1.0	1.0	0.7	0.7
7	Idle	2.7	1.0	1.0	0.3	0.4
16		2.7	1.0	1.0	0.6	0.6
20		3.3	1.0	1.0	0.9	0.7
		2.9	1.0	1.0	0.6	0.6
22	Idle-Accel	1.6	0.9	0.6	0.3	0.1
24		2.1	1.0	0.7	0.7	0.6
28		2.9	1.0	1.0	0.6	0.7
33		2.7	1.0	1.0	0.7	0.4
		2.3	1.0	0.8	0.6	0.5
23	Accel	2.1	1.0	0.9	0.4	0.3
26		2.6	1.0	1.0	0.6	0.4
29		2.9	1.0	1.0	0.9	0.6
32		2.7	1.0	1.0	0.4	0.6
		2.6	1.0	1.0	0.6	0.5
25	Decel	2.7	1.0	1.0	0.6	0.4
27		2.1	1.0	1.0	0.3	0.4
30		2.6	1.0	0.9	0.7	0.6
31		2.6	1.0	0.9	0.4	0.6
		2.6	1.0	1.0	0.5	0.5
	Cold Start	3.1	1.0	0.9	0.7	0.9

TABLE F-11. VEHICLE ODOR EVALUATION SUMMARY

Vehicle: Oldsmobile Diesel Car

Dilution Ratio: 550:1

Date: December 3, 1976

Run No.	Operating Condition	"D" Composite	"B" Burnt	"O" Oily	"A" Aromatic	"P" Pungent
9	Inter Speed	1.0	1.0	0.2	0	0
14	0 Load	1.1	0.6	0.2	0.5	0
19		1.2	0.9	0.2	0.3	0
		1.1	0.8	0.2	0.3	0
1	Inter Speed	1.0	0.8	0.3	0.2	0
8	Mid-Load	1.1	0.8	0.3	0.2	0.2
18		0.8	0.6	0.2	0.3	0
		1.0	0.7	0.3	0.2	0.1
5	Inter Speed	0.8	0.8	0.3	0	0
12	High Load	0.8	0.8	0.2	0.2	0
20		0.8	0.5	0.2	0.3	0
		0.8	0.7	0.2	0.2	0
3	High Speed	0.8	0.7	0.3	0	0
11	0 Load	1.0	0.9	0.3	0.2	0
21		1.0	0.8	0.2	0.3	0
		0.9	0.8	0.3	0.2	0
4	High Speed	1.1	0.8	0.3	0.2	0
13	Mid-Load	1.0	0.6	0.2	0.4	0
17		1.0	0.6	0.2	0.3	0
		1.0	0.7	0.2	0.3	0
7	High Speed	1.0	0.8	0.3	0.2	0
10	High Load	0.9	0.9	0.2	0	0
16		1.0	0.8	0.3	0.3	0.2
		1.0	0.8	0.3	0.2	0.1
2	Idle	0.7	0.6	0.3	0.2	0
6		0.8	0.8	0.3	0	0
15		0.9	0.5	0.2	0.3	0
		0.8	0.6	0.3	0.2	0
22	Idle-Accel	1.0	0.9	0.5	0.2	0
27		1.2	0.8	0.4	0.4	0.2
31		0.8	0.7	0.3	0.2	0
33		0.9	0.8	0.2	0.2	0
		1.0	0.8	0.4	0.3	0.1
23	Accel	1.1	0.9	0.2	0.2	0
26		0.8	0.8	0.2	0.2	0
29		0.8	0.5	0.3	0.2	0
32		1.4	1.0	0.4	0.2	0
		1.0	0.8	0.3	0.2	0
24	Decel	1.4	1.0	0.4	0.2	0.2
25		1.2	1.0	0.4	0.2	0
28		1.2	0.8	0.5	0.2	0
30		1.2	0.6	0.6	0.2	0
		1.3	0.9	0.5	0.2	0.1
	Cold Start	2.0	1.0	1.0	0.2	0.2

TABLE F-12. COMPARISON OF ODOR PANEL RATINGS

VEHICLE: VW Rabbit

Operating Condition	Date	Dilution Ratio	"D" Composite	"B" Burnt	"O" Oily	"A" Aromatic	"P" Pungent
Inter Speed 0 Load	12/13/76	100:1	3.3	1.1	0.9	0.7	0.7
	12/15/76	100:1	2.3	1.0	0.8	0.6	0.3
	Average	100:1	2.8	1.1	0.9	0.7	0.5
	12/17/76	550:1	0.9	0.7	0.3	0.1	0
Inter Speed Mid Load	12/13/76	100:1	3.1	1.1	1.0	0.7	0.7
	12/15/76	100:1	2.5	1.0	1.0	0.4	0.4
	Average	100:1	2.8	1.1	1.0	0.6	0.6
	12/17/76	550:1	1.1	0.7	0.3	0.2	0.1
Inter Speed High Load	12/13/76	100:1	3.5	1.1	1.0	0.7	0.8
	12/15/76	100:1	3.1	1.1	1.0	0.5	0.7
	Average	100:1	3.3	1.1	1.0	0.6	0.8
	12/17/76	550:1	1.3	0.7	0.4	0.4	0.1
High Speed 0 Load	12/13/76	100:1	2.3	1.0	0.9	0.4	0.3
	12/15/76	100:1	2.2	1.0	1.0	0.4	0.2
	Average	100:1	2.3	1.0	1.0	0.4	0.3
	12/17/76	550:1	0.9	0.6	0.2	0.2	0.1
High Speed Mid Load	12/13/76	100:1	3.8	1.3	1.0	0.6	1.0
	12/15/76	100:1	3.2	1.1	1.0	0.5	0.8
	Average	100:1	3.5	1.2	1.0	0.6	0.9
	12/17/76	550:1	0.9	0.6	0.5	0.1	0
High Speed High Load	12/13/76	100:1	3.8	1.2	1.1	0.9	0.8
	12/15/76	100:1	3.7	1.2	1.0	0.7	0.9
	Average	100:1	3.8	1.2	1.1	0.8	0.9
	12/17/76	550:1	1.3	0.9	0.5	0.2	0
Idle	12/13/76	100:1	3.7	1.1	0.9	0.9	0.8
	12/15/75	100:1	3.4	1.1	1.0	0.6	0.7
	Average	100:1	3.6	1.1	1.0	0.8	0.8
	12/17/76	550:1	1.2	0.9	0.3	0.2	0.1
Idle-Accel	12/13/76	100:1	3.4	1.1	1.0	0.7	0.1
	12/15/76	100:1	3.5	1.2	1.0	0.7	0.9
	Average	100:1	3.5	1.2	1.0	0.7	1.0
	12/17/76	550:1	0.8	0.7	0.3	0.3	0.1
Acceleration	12/13/76	100:1	3.6	1.2	1.0	0.8	0.8
	12/15/76	100:1	3.7	1.3	1.0	0.7	0.9
	Average	100:1	3.7	1.3	1.0	0.8	0.9
	12/17/76	550:1	1.3	0.9	0.5	0.3	0.2
Deceleration	12/13/76	100:1	3.3	1.0	1.0	0.9	0.7
	12/15/76	100:1	3.3	1.1	1.0	0.8	0.7
	Average	100:1	3.3	1.1	1.0	0.9	0.7
	12/17/76	550:1	0.9	0.8	0.3	0.3	0.1
Cold Start	12/13/76	100:1	4.3	1.2	1.0	1.0	1.0
	12/15/76	100:1	3.7	1.3	1.0	0.7	0.7
	Average	100:1	4.0	1.3	1.0	0.9	0.9
	12/17/76	550:1	2.4	1.0	1.0	0.4	0.3

TABLE F-13. VEHICLE ODOR EVALUATION SUMMARY

Vehicle: VW Rabbit Diesel Car
Date: December 13, 1976

Dilution Ratio: 100:1

Run No.	Operating Condition	"D" Composite	"B" Burnt	"O" Oily	"A" Aromatic	"P" Pungent
9	Inter Speed 0 Load	3.3	1.2	1.0	0.7	0.7
14		4.0	1.0	1.0	1.0	1.0
19		2.7	1.0	0.8	0.5	0.3
		3.3	1.1	0.9	0.7	0.7
1	Inter Speed Mid-Load	3.7	1.3	1.0	1.0	0.8
8		2.5	1.0	1.0	0.3	0.5
18		3.2	1.0	1.0	0.7	0.7
		3.1	1.1	1.0	0.7	0.7
5	Inter Speed High Load	3.8	1.0	1.0	1.0	0.8
12		3.3	1.0	1.0	0.7	0.5
20		3.5	1.2	1.0	0.3	1.0
		3.5	1.1	1.0	0.7	0.8
3	High Speed 0 Load	2.3	1.0	1.0	0.3	0.2
11		2.8	1.0	1.0	0.7	0.5
21		1.8	1.0	0.7	0.3	0.3
		2.3	1.0	0.9	0.4	0.3
4	High Speed Mid-Load	4.5	1.5	1.0	0.8	1.0
13		4.0	1.3	1.0	0.7	1.2
17		3.0	1.2	1.0	0.3	0.8
		3.8	1.3	1.0	0.6	1.0
7	High Speed High Load	4.3	1.3	1.2	0.8	1.0
10		3.3	1.0	1.0	1.0	0.5
16		3.8	1.2	1.0	1.0	0.8
		3.8	1.2	1.1	0.9	0.8
2	Idle	3.5	1.0	0.8	1.0	0.7
6		3.5	1.0	1.0	1.0	0.7
15		4.2	1.3	1.0	0.8	1.0
		3.7	1.1	0.9	0.9	0.8
22	Idle-Accel	3.7	1.2	1.0	0.7	1.2
24		3.2	1.0	1.0	0.7	0.8
28		3.3	1.0	1.0	0.8	0.8
33		3.5	1.0	1.0	0.5	1.0
		3.4	1.1	1.0	0.7	1.0
23	Accel	3.7	1.3	1.0	0.7	0.8
26		3.2	1.0	1.0	0.8	0.5
29		3.8	1.0	1.0	1.0	1.0
32		3.8	1.3	1.0	0.7	0.8
		3.6	1.2	1.0	0.8	0.8
25	Decel	3.2	1.0	1.0	0.8	0.7
27		3.2	1.0	1.0	0.8	0.7
30		3.3	1.0	1.0	0.8	0.7
31		3.3	1.0	1.0	1.0	0.5
		3.3	1.0	1.0	0.9	0.7
	Cold Start	4.3	1.2	1.0	1.0	1.0

TABLE F-14. VEHICLE ODOR EVALUATION SUMMARY

Vehicle: VW Rabbit Diesel Car — Dilution Ratio: 100:1
Date: December 15, 1976

Run No.	Operating Condition	"D" Composite	"B" Burnt	"O" Oily	"A" Aromatic	"P" Pungent
7	Inter Speed	2.6	1.0	0.9	0.7	0.4
11	0 Load	2.9	1.0	1.0	0.6	0.4
18		1.4	0.9	0.6	0.6	0.1
		2.3	1.0	0.8	0.6	0.3
5	Inter Speed	2.9	1.0	1.0	0.6	0.7
8	Mid-Load	2.3	1.0	1.0	0.3	0.3
21		2.3	1.0	1.0	0.4	0.1
		2.5	1.0	1.0	0.4	0.4
1	Inter Speed	3.4	1.3	0.9	0.4	0.7
13	High Load	2.7	1.0	1.0	0.4	0.6
17		3.3	1.0	1.0	0.6	0.9
		3.1	1.1	1.0	0.5	0.7
3	High Speed	2.3	1.0	1.0	0.3	0.3
14	0 Load	2.1	1.0	1.0	0.4	0.1
16		2.1	1.0	1.0	0.4	0.1
		2.2	1.0	1.0	0.4	0.2
2	High Speed	3.3	1.0	0.9	0.7	0.9
12	Mid-Load	3.0	1.0	1.0	0.6	0.7
19		3.3	1.3	1.0	0.3	0.9
		3.2	1.1	1.0	0.5	0.8
6	High Speed	3.7	1.3	1.0	0.9	1.0
9	High Load	3.4	1.3	1.0	0.6	0.9
20		3.9	1.1	1.0	0.7	0.9
		3.7	1.2	1.0	0.7	0.9
4	Idle	3.3	1.0	1.0	0.4	0.9
10		2.6	1.0	0.9	0.6	0.3
15		4.4	1.3	1.1	0.7	1.0
		3.4	1.1	1.0	0.6	0.7
23	Idle-Accel	3.3	1.3	1.0	0.7	0.9
25		3.3	1.0	1.0	0.6	0.9
27		3.6	1.1	1.0	0.6	0.9
30		3.6	1.3	0.9	0.7	0.9
		3.5	1.2	1.0	0.7	0.9
24	Accel	3.4	1.1	0.9	0.6	1.0
26		3.7	1.1	1.0	0.7	0.9
29		4.0	1.4	1.0	0.7	0.9
31		3.7	1.4	1.0	0.9	0.9
		3.7	1.3	1.0	0.7	0.9
22	Decel	2.6	1.0	0.9	0.6	0.4
28		3.3	1.1	0.9	0.9	0.9
32		3.4	1.0	1.0	0.9	0.9
33		3.7	1.1	1.0	0.9	0.7
		3.3	1.1	1.0	0.8	0.7
	Cold Start	3.7	1.3	1.0	0.7	0.7

TABLE F-15. VEHICLE ODOR EVALUATION SUMMARY

Vehicle: VW Rabbit

Date: December 17, 1976

Dilution Ratio: 550:1

Run No.	Operating Condition	"C" Composite	"B" Burnt	"O" Oily	"A" Aromatic	"P" Pungent
4	Inter Speed	0.7	0.5	0.4	0.1	0
9	0 Load	0.6	0.6	0.2	0.1	0
14		1.4	0.9	0.4	0.1	0
		0.9	0.7	0.3	0.1	0
8	Inter Speed	0.9	0.8	0.4	0.1	0
13	Mid-Load	1.7	1.0	0.4	0.3	0.2
16		0.7	0.4	0.1	0.1	0.1
		1.1	0.7	0.3	0.2	0.1
2	Inter Speed	0.8	0.6	0.4	0.3	0.1
10	High Load	2.6	1.0	0.7	0.6	0.3
20		0.6	0.4	0.1	0.2	0
		1.3	0.7	0.4	0.4	0.1
1	High Speed	1.1	0.9	0.5	0.3	0.1
18	0 Load	0.9	0.6	0.1	0.1	0.1
21		0.6	0.4	0.1	0.2	0
		0.9	0.6	0.2	0.2	0.1
3	High Speed	0.8	0.5	0.4	0.1	0.1
7	Mid-Load	1.4	1.0	0.9	0.1	0
19		0.6	0.4	0.1	0.1	0
		0.9	0.6	0.5	0.1	0
6	High Speed	1.3	1.0	0.4	0.1	0
12	High Load	1.8	1.0	0.9	0.4	0.1
15		0.8	0.7	0.1	0.1	0
		1.3	0.9	0.5	0.2	0
5	Idle	1.0	0.9	0.1	0.1	0.1
11		1.9	1.0	0.6	0.3	0.3
17		0.8	0.8	0.3	0.1	0
		1.2	0.9	0.3	0.2	0.1
24	Idle-Accel	1.2	0.8	0.4	0.4	0.1
26		0.8	0.7	0.4	0.4	0.1
29		0.6	0.6	0.1	0.1	0
32		0.7	0.7	0.1	0.1	0
		0.8	0.7	0.3	0.3	0.1
22	Accel	1.7	0.9	0.9	0.3	0.3
25		1.1	0.9	0.3	0.4	0.3
28		1.4	0.8	0.5	0.3	0.3
31		0.9	0.9	0.1	0.1	0
		1.3	0.9	0.5	0.3	0.2
23	Decel	1.2	0.9	0.3	0.4	0.1
27		0.8	0.6	0.4	0.4	0.1
30		0.9	0.9	0.3	0.3	0.1
33		0.6	0.6	0.1	0.1	0
		0.9	0.8	0.3	0.3	0.1
	Cold Start	2.4	1.0	1.0	0.4	0.3

TABLE F-16. COMPARISON OF GASEOUS EMISSION
Oldsmobile Diesel Car

Operating Condition	Date	HC, ppmC	CO, ppm	CO_2, %	NDIR NO, ppm	CL NO, ppm	CL NO_x ppm	DOAS Results LCA, µg/ℓ	DOAS Results LCO, µg/ℓ	DOAS Results TIA	Air Flow kg/min
Inter Speed	11/29/76	119	330	1.9	103	82	82	14.3	6.7	1.8	0.61
0 Load	12/01/76	149	330	2.1	63	---	---	13.6	5.3	1.7	0.61
	Average	134	330	2.0	83	82	82	14.0	6.0	1.8	0.61
	12/03/76	148	297	2.1	86	76	76	----	---	---	0.59
	3-day Avg	139	319	2.0	84	79	79	----	---	---	0.60
Inter Speed	11/29/76	87	302	4.6	214	177	177	16.7	6.1	1.8	0.61
Mid-Load	12/01/76	107	311	4.8	187	---	---	15.4	5.9	1.8	0.62
	Average	97	307	4.7	201	177	177	16.1	6.0	1.8	0.62
	12/03/76	111	283	4.7	194	173	173	----	---	---	0.60
	3-day Avg	102	299	4.7	198	175	175	----	---	---	0.61
Inter Speed	11/29/76	80	339	6.8	276	221	221	13.6	5.1	1.7	0.62
High Load	12/01/76	88	311	6.9	221	---	---	15.3	6.1	1.8	0.62
	Average	84	325	6.9	249	221	221	14.5	5.6	1.8	0.62
	12/03/76	105	297	7.3	256	222	222	----	---	---	0.63
	3-day Avg	91	316	7.0	251	222	222	----	---	---	0.62
High Speed	11/29/76	128	359	2.3	105	80	80	14.2	6.5	1.8	0.92
0 Load	12/01/76	147	354	2.2	73	---	---	16.6	6.5	1.8	0.90
	Average	138	357	2.3	89	80	80	15.4	6.5	1.8	0.91
	12/03/76	167	292	2.3	85	77	77	----	---	---	0.89
	3-day Avg	147	335	2.3	88	79	79	----	---	---	0.90
High Speed	11/29/76	80	339	6.4	274	232	232	13.4	5.0	1.5	0.91
Mid-Load	12/01/76	91	292	6.5	246	---	---	17.3	5.8	1.7	0.91
	Average	86	316	6.5	260	232	232	15.4	5.4	1.6	0.91
	12/03/76	106	292	6.6	268	230	230	----	---	---	0.88
	3-day Avg	92	308	6.5	263	231	231	----	---	---	0.90
High Speed	11/29/76	77	540	10.4	305	263	263	13.2	7.2	1.9	0.91
High Load	12/01/76	92	564	10.6	270	---	---	11.1	6.9	1.8	0.91
	Average	85	552	10.5	288	263	263	12.2	7.1	1.9	0.91
	12/03/76	85	539	10.9	296	263	263	----	---	---	0.88
	3-day Avg	85	548	10.6	290	263	263	----	---	---	0.90
Idle	11/29/76	257	549	2.4	64	56	56	19.7	4.7	1.5	0.26
	12/01/76	269	511	2.4	53	---	---	17.0	5.1	1.7	0.25
	Average	263	530	2.4	59	56	56	18.4	4.9	1.6	0.26
	12/03/76	326	502	2.4	58	53	53	----	---	---	0.26
	3-day Avg	284	521	2.4	58	55	55	----	---	---	0.26

TABLE F-17. GASEOUS EMISSIONS SUMMARY

Vehicle: Oldsmobile Diesel Car
Date: November 29, 1976

					NDIR	CL		DOAS Results			
Run No.	Operating Condition	HC, ppmC	CO, ppm	CO_2, %	NO, ppm	NO, ppm	NO_x ppm	LCA, µg/ℓ	LCO, µg/ℓ	TIA	Air Flow kg/min
9	Inter Speed	116	311	2.0	95	80	80	11.5	4.2	1.6	0.61
14	0 Load	122	340	2.0	99	80	80	16.0	8.7	1.9	0.62
19		120	340	1.7	115	85	85	15.3	7.2	1.9	0.60
		119	330	1.9	103	82	82	14.3	6.7	1.8	0.61
1	Inter Speed	84	297	4.8	206	175	175	24.2	7.8	1.9	0.62
8	Mid Load	84	283	4.4	222	175	175	10.9	4.1	1.6	0.60
18		94	325	4.5	214	180	180	14.9	6.4	1.8	0.61
		87	302	4.6	214	177	177	16.7	6.1	1.8	0.61
5	Inter Speed	68	368	6.9	280	210	210	11.6	4.0	1.6	0.63
12	High Load	86	325	7.0	272	230	230	10.4	3.2	1.5	0.62
20		86	325	6.5	276	225	225	18.9	8.0	1.9	0.61
		80	339	6.8	276	221	221	13.6	5.1	1.7	0.62
3	High Speed	120	368	2.2	91	75	75	14.3	5.4	1.7	0.93
11	0 Load	132	340	2.2	95	80	80	13.3	5.4	1.7	0.92
21		132	368	2.5	130	85	85	15.0	8.8	1.9	0.92
		128	359	2.3	105	80	80	14.2	6.5	1.8	0.92
4	High Speed	78	369	6.7	280	230	230	8.3	0.6	0.8	0.91
13	Mid Load	66	325	6.3	276	235	235	16.7	7.7	1.9	0.91
17		96	325	6.2	267	235	235	15.2	6.8	1.8	0.90
		80	339	6.4	274	232	232	13.4	5.0	1.5	0.91
7	High Speed	80	511	10.4	301	250	250	5.4	5.7	1.8	0.92
10	High Load	60	540	10.4	313	270	270	16.4	6.8	1.8	0.90
16		92	568	10.4	301	270	270	17.7	9.2	2.0	0.90
		77	540	10.4	305	263	263	13.2	7.2	1.9	0.91
2	Idle	232	554	2.4	60	54	54	13.2	4.1	1.6	0.26
6		268	540	2.4	60	55	55	16.5	1.0	1.0	0.26
15		272	554	2.3	72	60	60	29.5	9.0	2.0	0.25
		257	549	2.4	64	56	56	19.7	4.7	1.5	0.26

TABLE F-18. GASEOUS EMISSIONS SUMMARY

Vehicle: Oldsmobile Diesel Car
Date: December 1, 1976

Run No.	Operating Condition	HC, ppmC	CO, ppm	CO_2, %	NDIR NO, ppm	DOAS Results LCA µg/ℓ	DOAS Results LCO µg/ℓ	DOAS Results TIA	Air Flow kg/min
3	Inter Speed	126	325	2.1	49	13.9	5.8	1.8	0.61
8	0 Load	168	311	2.0	68	14.5	5.5	1.7	0.61
13		152	354	2.1	72	12.5	4.6	1.7	0.62
		149	330	2.1	63	13.6	5.3	1.7	0.61
4	Inter Speed	102	311	4.7	158	15.1	5.6	1.8	0.62
14	Mid Load	98	311	4.6	186	13.0	5.2	1.7	0.62
21		120	311	5.2	218	18.2	7.0	1.9	0.61
		107	311	4.8	187	15.4	5.9	1.8	0.62
2	Inter Speed	96	340	7.1	202	22.3	8.4	1.9	0.62
10	High Load	88	311	6.9	226	13.2	4.6	1.7	0.62
17		80	283	6.6	235	10.3	5.3	1.7	0.63
		88	311	6.9	221	15.3	6.1	1.8	0.62
1	High Speed	142	397	2.2	52	22.0	7.1	1.9	0.90
11	0 Load	152	354	2.2	76	13.9	6.0	1.8	0.91
19		148	311	2.2	91	13.9	6.3	1.8	0.89
		147	354	2.2	73	16.6	6.5	1.8	0.90
5	High Speed	94	311	6.7	243	20.6	4.0	1.6	0.90
9	Mid Load	108	297	6.4	243	22.5	8.5	1.9	0.91
18		72	268	6.3	251	8.9	4.8	1.7	0.91
		91	292	6.5	246	17.3	5.8	1.7	0.91
6	High Speed	140	626	11.2	259	12.9	8.2	1.9	0.90
12	High Load	72	511	10.3	276	12.0	7.6	1.9	0.91
15		64	554	10.4	276	8.5	4.9	1.7	0.92
		92	564	10.6	270	11.1	6.9	1.8	0.91
7	Idle	292	540	2.5	38	17.4	4.2	1.6	0.25
16		212	454	2.3	53	13.0	4.1	1.6	0.25
20		302	540	2.4	68	20.7	7.1	1.9	0.25
		269	511	2.4	53	17.0	5.1	1.7	0.25

TABLE F-19. GASEOUS EMISSIONS SUMMARY

Vehicle: Oldsmobile Diesel Car
Date: December 3, 1976

					NDIR	CL		
Run No.	Operating Condition	HC, ppmC	CO, ppm	CO_2 %	NO, ppm	NO, ppm	NO_x ppm	Air Flow kg/min
9	Inter Speed	144	297	2.1	87	80	80	0.60
14	0 Load	160	297	2.1	87	75	75	0.59
19		140	297	2.1	87	72	72	0.59
		148	297	2.1	86	76	76	0.59
1	Inter Speed	122	268	4.8	186	170	170	0.61
8	Mid Load	108	283	4.8	194	180	180	0.59
18		104	297	4.5	202	170	170	0.60
		111	283	4.7	194	173	173	0.60
5	Inter Speed	108	283	7.5	239	220	220	0.63
12	High Load	116	311	7.0	267	220	220	0.63
20		92	297	7.4	263	225	225	0.62
		105	297	7.3	256	222	222	0.63
3	High Speed	156	254	2.3	84	80	80	0.89
11	0 Load	176	283	2.2	87	75	75	0.89
21		170	340	2.4	84	80	80	0.88
		167	292	2.3	85	77	77	0.89
4	High Speed	124	283	6.9	251	230	230	0.88
13	Mid Load	106	311	6.4	280	230	230	0.88
17		88	283	6.4	272	230	230	0.88
		106	292	6.6	268	230	230	0.88
7	High Speed	96	511	11.4	284	270	270	0.88
10	High Load	60	597	10.8	292	260	260	0.87
16		98	511	10.6	313	260	260	0.88
		85	539	10.9	296	263	263	0.88
2	Idle	310	497	2.4	52	52	52	0.26
6		284	468	2.5	64	55	55	0.26
15		384	540	2.4	57	52	52	0.26
		326	502	2.4	58	53	53	0.26

TABLE F-20. COMPARISON OF GASEOUS EMISSIONS
VW Rabbit Diesel Car

					NDIR	CL		DOAS Results			
Operating Condition	Date	HC, ppmC	CO, ppm	CO_2, %	NO, ppm	NO, ppm	NO_x ppm	LCA, µg/ℓ	LCO, µg/ℓ	TIA	Air Flow kg/min
Inter Speed 0 Load	12/13/76	90	301	2.0	86	73	73	8.2	3.5	1.5	1.50
	12/15/76	56	245	2.0	53	63	63	2.4	1.7	1.2	1.46
	12/17/76	53	226	1.9	67	58	58	----	----	---	1.48
	Average	66	257	2.0	69	65	65	5.3	2.6	1.4	1.48
Inter Speed Mid Load	12/13/76	92	197	6.6	301	262	262	19.2	5.8	1.8	1.49
	12/15/76	63	178	6.6	292	282	282	10.0	4.4	1.7	1.51
	12/17/76	51	169	6.0	301	266	266	----	----	---	1.49
	Average	69	181	6.4	298	270	270	14.6	5.1	1.8	1.50
Inter Speed High Load	12/13/76	65	278	11.9	326	325	325	15.8	6.1	1.8	1.42
	12/15/76	103	373	12.7	301	285	285	14.8	6.2	1.8	1.43
	12/17/76	94	382	13.0	315	277	277	----	----	---	1.41
	Average	87	344	12.5	314	296	296	15.3	6.2	1.8	1.42
High Speed 0 Load	12/13/76	61	245	2.4	127	107	107	9.3	3.1	1.5	2.43
	12/15/76	49	226	2.3	104	100	100	5.8	2.5	1.4	2.44
	12/17/76	45	221	2.3	115	98	98	----	----	---	2.48
	Average	52	231	2.3	115	102	102	7.6	2.8	1.5	2.45
High Speed Mid Load	12/13/76	137	349	7.7	425	385	385	26.9	7.9	1.9	2.44
	12/15/76	161	378	7.5	386	378	378	18.8	5.7	1.8	2.52
	12/17/76	89	282	7.4	389	357	357	----	----	---	2.41
	Average	129	336	7.5	400	373	373	22.9	6.8	1.9	2.46
High Speed High Load	12/13/76	109	1806	14.2	364	328	322	24.4	10.3	2.0	2.37
	12/15/76	97	1778	13.9	346	330	330	22.5	11.1	2.0	2.39
	12/17/76	73	2497	13.6	334	315	315	----	----	---	2.38
	Average	93	2027	13.9	348	324	322	23.5	10.7	2.0	2.38
Idle	2/13/76	180	383	2.2	114	93	92	8.1	3.4	1.5	0.63
	2/15/76	216	445	2.1	82	87	87	10.5	3.7	1.6	0.61
	2/17/76	157	349	2.1	110	93	93	----	----	---	0.63
	Average	184	392	2.1	102	91	91	9.3	3.6	1.6	0.62

TABLE F-21. GASEOUS EMISSIONS SUMMARY

Vehicle: VW Rabbit
Date: December 13, 1976

					NDIR	CL		DOAS Results			
Run No.	Operating Condition	HC, ppmC	CO, ppm	CO_2, %	NO, ppm	NO, ppm	NO_x ppm	LCA, µg/ℓ	LCO, µg/ℓ	TIA	Air Flow kg/min
9	Inter Speed	104	268	2.0	76	65	65	12.7	4.7	1.7	1.52
14	0 Load	124	368	2.0	99	80	80	10.2	4.0	1.6	1.49
19		42	268	1.9	84	75	75	1.8	1.8	1.3	1.50
		90	301	2.0	86	73	73	8.2	3.5	1.5	1.50
1	Inter Speed	156	183	7.2	318	260	260	28.2	7.6	1.9	1.49
8	Mid Load	56	197	6.4	292	265	265	15.1	4.6	1.7	1.45
18		64	212	6.2	292	260	260	14.4	5.1	1.7	1.52
		92	197	6.6	301	262	262	19.2	5.8	1.8	1.49
5	Inter Speed	84	254	11.7	334	395	395	22.1	8.1	1.9	1.41
12	High Load	56	268	11.4	326	290	290	17.8	5.3	1.7	1.42
20		56	311	12.6	318	290	290	7.6	5.0	1.7	1.42
		65	278	11.9	326	325	325	15.8	6.1	1.8	1.42
3	High Speed	56	226	2.4	130	105	105	4.6	2.4	1.4	2.48
11	0 Load	80	240	2.4	130	110	110	13.7	3.0	1.5	2.40
21		48	268	2.4	122	105	105	9.5	4.0	1.6	2.40
		61	245	2.4	127	107	107	9.3	3.1	1.5	2.43
4	High Speed	168	340	7.9	425	385	385	31.2	9.5	2.0	2.47
13	Mid Load	136	368	7.4	421	380	380	22.5	6.2	1.8	2.47
17		108	340	7.7	430	390	390	----	----	---	2.39
		137	349	7.7	425	385	385	26.9	7.9	1.9	2.44
7	High Speed	84	2229	14.1	343	320	310	24.3	11.2	2.1	2.35
10	High Load	140	974	13.5	390	335	330	35.9	11.8	2.1	2.37
16		104	2214	15.0	360	330	325	13.0	7.9	1.9	2.39
		109	1806	14.2	364	328	322	24.4	10.3	2.0	2.37
2	Idle	180	397	2.2	119	95	95	7.6	3.3	1.5	0.64
6		112	283	2.2	115	95	95	5.6	2.7	1.4	0.62
15		248	468	2.2	107	90	85	11.2	4.1	1.6	0.63
		180	383	2.2	114	93	92	8.1	3.4	1.5	0.63

TABLE F-22. GASEOUS EMISSIONS SUMMARY

Vehicle: VW Rabbit Diesel Car
Date: December 15, 1976

					NDIR	CL		DOAS Results			
Run No.	Operating Condition	HC, ppmC	CO, ppm	CO_2, %	NO, ppm	NO, ppm	NO_x ppm	LCA, µg/ℓ	LCO, µg/ℓ	TIA	Air Flow kg/mile
7	Inter Speed	52	254	2.0	49	65	65	3.0	1.7	1.2	1.47
11	0 Load	68	268	1.9	53	65	65	2.4	1.6	1.2	1.50
18		48	212	2.0	57	60	60	1.8	1.7	1.2	1.41
		56	245	2.0	53	63	63	2.4	1.7	1.2	1.46
5	Inter Speed	88	183	6.7	284	290	290	13.0	4.8	1.7	1.56
8	Mid Load	50	169	7.0	292	285		11.1	4.8	1.7	1.50
21		50	183	6.0	301	270	270	5.9	3.6	1.6	1.48
		63	178	6.6	292	282	282	10.0	4.4	1.7	1.51
1	Inter Speed	88	482	12.7	292	280	280	20.6	7.1	1.9	1.41
13	High Load	60	240	11.4	318	290	290	11.0	4.5	1.7	1.43
17		160	397	14.1	292	285	285	12.8	7.1	1.9	1.46
		103	373	12.7	301	285	825	14.8	6.2	1.8	1.43
3	High Speed	56	212	2.2	107	105	105	4.8	2.5	1.4	2.45
14	0 Load	36	226	2.3	107	100	100	9.0	2.9	1.5	2.43
16		56	240	2.3	99	95	95	3.7	2.0	1.3	2.44
		49	226	2.3	104	100	100	5.8	2.5	1.4	2.44
2	High Speed	160	397	7.4	360	390	390	23.5	6.8	1.8	2.47
12	Mid Load	192	397	7.6	403	375	375	19.1	5.6	1.8	2.55
19		132	340	7.4	395	370	370	13.8	4.7	1.7	2.54
		161	378	7.5	386	378	378	18.8	5.7	1.8	2.52
6	High Speed	108	1326	13.5	352	350	350	19.4	10.9	2.0	2.39
9	High Load	120	1718	14.3	334	310	310	36.1	14.0	2.2	2.43
20		64	2291	13.8	352	330	330	11.9	8.3	1.9	2.34
		97	1778	13.9	346	330	330	22.5	11.1	2.0	2.39
4	Idle	224	454	2.1	68	90	90	11.9	4.5	1.7	0.61
10		144	340	2.2	103	90	90	6.0	1.8	1.3	0.61
15		280	540	2.1	76	80	80	13.7	4.8	1.7	0.62
		216	445	2.1	82	87	87	10.5	3.7	1.6	0.61

TABLE F-23. GASEOUS EMISSIONS SUMMARY

Vehicle: VW Rabbit
Date: December 17, 1976

					NDIR	CL		
Run No.	Operating Condition	HC, ppmC	CO, ppm	CO_2 %	NO, ppm	NO, ppm	NO_x ppm	Air Flow kg/min
4	Inter Speed	64	254	1.9	68	60	60	1.45
9	0 Load	56	226	1.9	60	55	55	1.48
14		40	197	1.9	72	60	60	1.50
		53	226	1.9	67	58	58	1.48
8	Inter Speed	50	155	5.7	301	275	275	1.49
13	Mid Load	52	183	6.2	301	265	265	1.50
16		52	169	6.2	301	260	260	1.47
		51	169	6.0	301	266	266	1.49
2	Inter Speed	100	368	12.6	288	275	275	1.43
10	High Load	140	397	12.9	297	275	275	1.39
20		44	382	13.6	360	280	280	1.41
		94	382	13.0	315	277	277	1.41
1	High Speed	72	226	2.3	107	98	98	2.53
18	0 Load	34	226	2.2	115	95	95	2.46
21		28	212	2.4	122	100	100	2.44
		45		2.3	115	98	98	2.48
3	High Speed	104	282	7.8	360	345	345	2.45
7	Mid Load	68	282	6.7	395	375	375	2.35
19		96	282	7.8	412	350	350	2.44
		89	282	7.4	389	357	357	2.41
6	High Speed	72	2352	12.6	334	325	325	2.36
12	High Load	72	2786	14.1	334	310	310	2.37
15		76	2352	14.1	334	310	310	2.40
		73	2497	13.6	334	315	315	2.38
5	Idle	212	425	2.1	103	90	90	0.63
11		128	282	2.1	115	100	100	0.64
17		132	340	2.1	111	90	90	0.63
		157	349	2.1	110	93	93	0.63

TABLE F-24. OLDS, CUTLASS, DIESEL, NOISE DATA - dBA SCALE

DATE: 1/7/77 WIND: 6.4 km/hr Northerly

Acceleration Test (1st Gear)

AMBIENT: Before Test 42-45 After Test 42-45

	Pass 1st	Pass 2nd	Pass 3rd	Arithmetic Average[2]
Exterior at 15.24m[1]				
Right to Left	73.5	73.0	74.0	73.8
Left to Right	73.0	72.5	73.0	73.2
Interior				
Fresh Air Blr Off	71.0	70.0	69.0	70.5
Fresh Air Blr On	73.5	74.0	74.5	74.2

Constant Speed 48.3 km/hr Driveby

AMBIENT: Before Test 42-45 After Test 42-45

	Pass 1st	Pass 2nd	Pass 3rd	Arithmetic Average[2]
Exterior at 15.24m				
Right to Left	61.0	60.0	59.5	60.5
Left to Right	61.5	61.0	61.0	61.2
Interior				
Fresh Air Blr Off	62.0	63.0	65.0	64.0
Fresh Air Blr On	72.5	72.0	71.5	72.2

Engine Idle, Vehicle at Rest

AMBIENT: Before Test After Test

	Test 1 Direction A (L-R)				Test 2 Direction B (R-L)				Max Reading
Interior	50.5 (70.5 Blr. On)				51.5 (71.0 Blr. On)				71.0
	Front	Rear	Left	Right	Front	Rear	Left	Right	
Exterior	69.0	60.5	66.5	69.0	7.00	61.5	69.0	69.5	70.0

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(1) According to SAE J-986a.

(2) Average of the two highest readings that are within 2dB of each other.

TABLE F-25. OLDS, CUTLASS, GASOLINE, NOISE DATA - dBA SCALE

DATE: 1/7/77 WIND: 6.4 km/hr Northerly

Acceleration Test (1st Gear)

AMBIENT: Before Test 42-45 After Test 42-45

	Pass			Arithmetic Average[2]
	1st	2nd	3rd	
Exterior at 15.24m[1]				
Right to Left	68.5	69.0	68.0	68.8
Left to Right	67.0	68.5	68.0	68.2
Interior				
Fresh Air Blr Off	68.0	69.0	68.5	68.8
Fresh Air Blr On	73.0	73.5	72.0	73.2

Constant Speed 48.3 km/hr Driveby

AMBIENT: Before Test 42-45 After Test 42-45

	Pass			Arithmetic Average[2]
	1st	2nd	3rd	
Exterior at 15.24m				
Right to Left	58.5	58.5	58.0	58.5
Left to Right	58.5	59.0	58.5	58.8
Interior				
Fresh Air Blr Off	61.0	59.0	60.0	60.5
Fresh Air Blr On	72.0	71.0	70.5	71.5

Engine Idle, Vehicle at Rest

AMBIENT: Before Test 42-45 After Test 42-45

	Test 1 Direction A (L-R)				Test 2 Direction B (R-L)				Max Reading
Interior	48.5 (71.5 Blr. On)				48.5 (70.5 Blr. On)				71.5
	Front	Rear	Left	Right	Front	Rear	Left	Right	
Exterior	64.5	60.0	62.5	62.5	63.5	60.0	62.5	62.0	64.5

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(1) According to SAE J-986a.

(2) Average of the two highest readings that are within 2dB of each other.

TABLE F-26. VW RABBIT DIESEL, NOISE DATA - dBA SCALE

DATE: 1/7/77 WIND: 3.0 km/hr Northerly

Acceleration Test (2nd Gear)

AMBIENT: Before Test 43-45 After Test 43-45

	Pass			Arithmetic Average[2]
	1st	2nd	3rd	
Exterior at 15.24m[1]				
Right to Left	71.0	71.5	71.5	71.5
Left to Right	70.5	70.0	71.0	70.8
Interior				
Fresh Air Blr Off	79.0	79.5	79.5	79.5
Fresh Air Blr On	80.0	80.0	80.0	80.0

Constant Speed 48.3 km/hr Driveby

AMBIENT: Before Test 43-45 After Test 43-45

	Pass			Arithmetic Average[2]
	1st	2nd	3rd	
Exterior at 15.24m				
Right to Left	59.0	58.0	58.0	58.5
Left to Right	59.0	57.5	57.5	58.2
Interior				
Fresh Air Blr Off	67.5	68.0	68.0	68.0
Fresh Air Blr On	71.5	72.0	71.5	71.8

Engine Idle, Vehicle at Rest

AMBIENT: Before Test 43-45 After Test 43-45

	Test 1 Direction A (L-R)				Test 2 Direction B (R-L)				Max Reading
Interior	59.5 (69.5 Blr. On)				62.5 (68.0 Blr. On)				69.5
	Front	Rear	Left	Right	Front	Rear	Left	Right	
Exterior	66.0	58.5	63.0	63.0	67.0	59.0	62.5	64.0	67.0

(1) According to SAE J-986a.

(2) Average of the two highest readings that are within 2dB of each other.

TABLE F-27. VW RABBIT, GAOLINE, NOISE DATA - dBA SCALE

DATE: 1/7/77 WIND: 3.0 km/hr Northerly

Acceleration Test (Gear)

AMBIENT: Before Test 43-45 After Test 43-45

	Pass			Arithmetic Average(2)
	1st	2nd	3rd	
Exterior at 15.24m(1)				
Right to Left	71.0	71.0	70.5	71.0
Left to Right	69.5	69.5	70.0	69.8
Interior				
Fresh Air Blr Off	75.0	77.0	76.0	76.5
Fresh Air Blr On	77.0	78.0	78.5	78.2

Constant Speed 48.3 km/hr Driveby

AMBIENT: Before Test 43-45 After Test 43-45

	Pass			Arithmetic Average(2)
	1st	2nd	3rd	
Exterior at 15.24m				
Right to Left	60.5	60.5	60.5	60.5
Left to Right	59.0	60.0	60.5	60.2
Interior				
Fresh Air Blr Off	70.0	69.5	71.0	70.5
Fresh Air Blr On	73.0	72.5	74.0	73.5

Engine Idle, Vehicle at Rest

AMBIENT: Before Test 43-45 After Test 43-45

	Test 1 Direction A (L-R)				Test 2 Direction B (R-L)				Max Reading
Interior	58.0 (69.5 Blr. On)				58.0 (69.5 Blr. On)				69.5
	Front	Rear	Left	Right	Front	Rear	Left	Right	
Exterior	62.0	65.0	63.5	62.0	61.5	64.5	63.5	62.0	65.0
Elect. Fan On (Cooling Fan)	72.5	65.5	66.0	64.0	71.0	65.0	66.0	64.0	73.5

(1) According to SAE J-986a.

(2) Average of the two highest readings that are within 2dB of each other.